

**Arsenic Removal from Drinking Water by Adsorptive Media
U.S. EPA Demonstration Project at Geneseo Hills Subdivision
in Geneseo, IL
Final Performance Evaluation Report**

by

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Sally Gutierrez, Director
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ABSTRACT

This report documents the activities performed and the results obtained from the arsenic removal treatment technology demonstration project at the Geneseo Hills Subdivision in Geneseo, IL. The main objective of the project was to evaluate the effectiveness of AdEdge Technologies' (AdEdge's) AD-33 adsorptive media (AM) system in removing arsenic to meet the new arsenic maximum contaminant level (MCL) of 10 µg/L. Additionally, this project evaluated (1) the reliability of the treatment system, (2) the required system operation and maintenance (O&M) and operator skill levels, and (3) the capital and O&M cost of the technology. The project also characterized the water in the distribution system and process residuals produced by the treatment process. The types of data collected included system operation, water quality (both across the treatment train and in the distribution system), process residuals, and capital and O&M cost.

The water system at the Geneseo Hills Subdivision was supplied primarily by one well, i.e., Well No. 5, to meet an average daily demand of 40,600 gal/day (gpd). The well water contained 19.6 µg/L (on average) of total arsenic (with approximately 73% existing as soluble As[III]), 554 µg/L (on average) of total iron (with 65% existing as soluble iron), and 8.0 µg/L (on average) of total manganese (with 100% existing as soluble manganese). The water also contained 1.3 mg/L (on average) of ammonia (as N) and 1.9 mg/L (on average) of total organic carbon (TOC).

The 200-gal/min (gpm) treatment system installed consisted of two 54-in × 60-in, 100 lb/in² (psi)-rated carbon steel vessels, configured in parallel to meet the rule-of-thumb peak flowrate of 165 gpm as required by Illinois Environmental Protection Agency (IL EPA). The actual peak flowrate recorded per readings of flow meters installed on the two adsorption vessels was 156 gpm. Each vessel contained approximately 10 ft³ of gravel underbedding overlain by 49 ft³ of AD-33 media, an iron-based, dry granular media manufactured by Lanxess and marketed by Severn Trent Services (STS) in the U.S. Because the system was placed downstream of one 12,000-gal and one 9,000-gal hydropneumatic (hydro) tank (pre-existing), the system was operating on-demand. Instantaneous flowrates recorded during the demonstration period from May 8, 2008, through July 30, 2010, averaged 32 gpm, significantly lower than the design flowrate of 200 gpm. This reduced average flowrate corresponded to a hydraulic loading rate of 1.0 gpm/ft² and an empty bed contact time (EBCT) of 22.9 min, compared to the respective design values of 6.3 gpm/ft² and 3.7 min.

The pre-existing chlorine addition system was used to oxidize soluble As(III) to soluble As(V) and maintain a target total chlorine residual of 1.2 mg/L (as Cl₂) in the distribution system. Because the addition point was upstream of the two hydro tanks and because on-demand flowrates were much lower than the design flowrate, a residence time as long as 11 hr (on average) was realized as chlorinated water travelled through the tanks. As a consequence, some solids, including arsenic laden iron particles, settled in the tanks, causing a decrease in both total iron (207 µg/L [on average]) and total arsenic concentrations (much less at 0.4 µg/L [on average]) in the tank effluent. As much as 19.2 µg/L of total arsenic still existed in the adsorption system influent with 9.4 µg/L existing as soluble As(V) and 8.6 µg/L as particulate arsenic.

From May 8, 2008, through July 30, 2010, the Well No. 5 pump operated for a total of 2,147 hr. The amount of water treated by the system was 33,158,000 gal (or 45,230 bed volumes [BV]). Total arsenic concentrations were removed to below 3.3 µg/L, presumably via soluble As(V) adsorption and particulate arsenic filtration. Backwash at a frequency of once every 45 days (on average) appeared to be effective in removing solids accumulating in the media beds. During each backwash event, as much as 8.2 lb of solids constituting mainly iron in 3,915 gal of wastewater was discharged into a backwash holding tank. The use of a backwash reclaim system was required because a sewer system was not available to receive

wastewater in the Geneseo Hills Subdivision and because backwash wastewater could not be used for irrigation purposes per IL EPA guidelines. Supernatant in the backwash holding tank was recycled at 12 gpm (<10% of the incoming well flowrate of 220 gpm [on average]) to a point upstream of the chlorine addition point and the sludge accumulated in the backwash holding tank was transferred to a sludge holding tank for air drying and final disposal. Sludge disposal did not occur during the performance evaluation study.

One operational issue encountered during system operation was clogging of bag filters during system backwash. The problem stemmed from a system design issue, which involved placing the bag filter assembly upstream (rather than downstream) of the backwash holding tank. As a result, the operator had to incrementally increase the nominal pore size of filter bags from 25 to 50 μm and then to 100 μm and replace clogged filter bags as many as three times during each vessel backwash. The plan was to relocate the bag filter assembly to downstream of the backwash holding tank but the relocation did not occur during the performance evaluation study.

Comparison of the distribution system sampling results before and after system startup showed a decrease in arsenic from 18.1 to 4.4 $\mu\text{g/L}$ (on average) and iron concentrations from 272 to 85 $\mu\text{g/L}$ (on average) based on results from two sampling locations in the Subdivision's historic sampling network under the Lead and Copper Rule (LCR) and one non-LCR location. There was evidence to suggest that some redissolution and/or resuspension of arsenic and iron had occurred. Average lead concentrations at two LCR locations were reduced from 2.9 to 1.3 $\mu\text{g/L}$ after system startup. Average copper concentrations at the two LCR locations were reduced from 946 to 670 $\mu\text{g/L}$. Before system startup, two copper (Cu) exceedances over the 1,300- $\mu\text{g/L}$ action level were noted at one LCR location.

The capital investment cost for the system was \$139,149, including \$101,290 for equipment, \$19,545 for site engineering, and \$18,314 for installation. Using the system's rated capacity of 200 gpm (288,000 gpd), the normalized capital cost was \$696/gpm (\$0.48/gpd). The incremental O&M cost was \$0.05/1,000 gal for labor plus the unit cost for media replacement, which can be estimated based on a projected media run length.

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ABBREVIATIONS AND ACRONYMS

Δp	differential pressure
AAL	American Analytical Laboratories
AM	adsorptive media
APU	arsenic package unit
As	arsenic
ATS	aquatic treatment system
BET	Brunauer, Emmett, and Teller
bgs	below ground surface
BV	bed volume
Ca	calcium
C/F	coagulation/filtration process
Cl	chlorine
CRF	capital recovery factor
Cu	copper
DBPs	disinfection byproducts
DO	dissolved oxygen
EBCT	empty bed contact time
EPA	U.S. Environmental Protection Agency
F	fluorine
Fe	iron
gpd	gallons per day
gpm	gallons per minute
HAA5	haloacetic acids
HDPE	high-density polyethylene
hp	horsepower
HIX	hybrid ion exchange
ICP-MS	inductively coupled plasma-mass spectrometry
ID	identification
IL EPA	Illinois Environmental Protection Agency
IR	iron removal
IX	ion exchange
LCR	Lead and Copper Rule
MCL	maximum contaminant level
MDL	method detection limit
MEI	Magnesium Elektron, Inc.

ABBREVIATIONS AND ACRONYMS (Continued)

Mg	magnesium
Mn	manganese
mV	millivolts
Na	sodium
NA	not analyzed
NaOCl	sodium hypochlorite
ND	not detectable
NRMRL	National Risk Management Research Laboratory
NSF	NSF International
NTU	nephelometric turbidity units
O&M	operation and maintenance
OIT	Oregon Institute of Technology
ORD	Office of Research and Development
ORP	oxidation-reduction potential
PLC	programmable logic controller
PO ₄	orthophosphate
POU	point of use
psi	pounds per square inch
PVC	polyvinyl chloride
QAPP	Quality Assurance Project Plan
QA/QC	quality assurance/quality control
RFP	request for proposals
RO	reverse osmosis
RPD	relative percent difference
SDWA	Safe Drinking Water Act
SiO ₂	silica
SMCL	secondary maximum contaminant level
SO ₄ ²⁻	sulfate
STS	Severn Trent Services
TCLP	toxicity characteristic leaching procedure
TDH	total dynamic head
TDS	total dissolved solids
TOC	total organic carbon
TSS	total suspended solids
TTHM	total trihalomethanes
U	uranium
V	vanadium
VOC	volatile organic compound

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1.0 INTRODUCTION

1.1 Background

The Safe Drinking Water Act (SDWA) mandates that the U. S. Environmental Protection Agency (EPA) identify and regulate drinking water contaminants that may have adverse human health effects and that are known or anticipated to occur in public water supply systems. In 1975, under the SDWA, EPA established a maximum contaminant level (MCL) for arsenic (As) at 0.05 mg/L. Amended in 1996, the SDWA required that EPA develop an arsenic research strategy and publish a proposal to revise the arsenic MCL by January 2000. On January 18, 2001, EPA finalized the arsenic MCL at 0.01 mg/L (EPA, 2001). In order to clarify the implementation of the original rule, EPA revised the rule text on March 25, 2003, to express the MCL as 0.010 mg/L (10 µg/L) (EPA, 2003). The final rule required all community and non-transient, non-community water systems to comply with the new standard by January 23, 2006.

In October 2001, EPA announced an initiative for additional research and development of cost-effective technologies to help small community water systems (<10,000 customers) meet the new arsenic standard, and to provide technical assistance to operators of small systems to reduce compliance costs. As part of this Arsenic Rule Implementation Research Program, EPA's Office of Research and Development (ORD) proposed a project to conduct a series of full-scale, on-site demonstrations of arsenic removal technologies, process modifications, and engineering approaches applicable to small systems. Shortly thereafter, an announcement was published in the *Federal Register* requesting water utilities interested in participating in Round 1 of this EPA-sponsored demonstration program to provide information on their water systems. In June 2002, EPA selected 17 out of 115 sites to host the demonstration studies.

In September 2002, EPA solicited proposals from engineering firms and vendors for cost-effective arsenic removal treatment technologies for the 17 host sites. EPA received 70 technical proposals for the 17 host sites, with each site receiving from one to six proposals. In April 2003, an independent technical panel reviewed the proposals and provided its recommendations to EPA on the technologies that it determined were acceptable for the demonstration at each site. Because of funding limitations and other technical reasons, only 12 of the 17 sites were selected for the demonstration project. Using the information provided by the review panel, EPA, in cooperation with the host sites and the drinking water programs of the respective states, selected one technical proposal for each site.

In 2003, EPA initiated Round 2 arsenic technology demonstration projects that were partially funded with Congressional add-on funding to the EPA budget. In June 2003, EPA selected 32 potential demonstration sites. In September 2003, EPA again solicited proposals from engineering firms and vendors for arsenic removal technologies. EPA received 148 technical proposals for the 32 host sites, with each site receiving from two to eight proposals. In April 2004, another technical panel was convened by EPA to review the proposals and provide recommendations to EPA with the number of proposals per site ranging from none (for two sites) to a maximum of four. The final selection of the treatment technology at the sites that received at least one proposal was made, again, through a joint effort by EPA, the state regulators, and the host site. Since then, four sites have withdrawn from the demonstration program, reducing the number of sites to 28.

With additional funding from Congress, EPA selected 10 more sites for demonstration under Round 2a. Somewhat different from the Round 1 and Round 2 selection process, Battelle, under EPA's guidance, issued a Request for Proposal (RFP) on February 14, 2007, to solicit technology proposals from vendors and engineering firms. Upon closing of the RFP on April 13, 2007, Battelle received from 14 vendors a total of 44 proposals, which were reviewed by a three-expert technical review panel convened at EPA on May 2 and 3, 2007. Copies of the proposals and recommendations of the review panel were later

provided to and discussed with representatives of the 10 host sites and state regulators in a technology selection meeting held at each host site during April through August 2007. The final selections of the treatment technology were made, again, through a joint effort by EPA, the respective state regulators, and the host sites. Based on discussions at the technology selection meeting, a 200-gal/min (gpm) AdEdge arsenic removal system using AD-33 adsorptive media (AM) was selected for demonstration at the Geneseo Hills Subdivision in Geneseo, IL.

As of June 2011, all 50 systems were operational and the performance evaluations of 49 systems were completed.

1.2 Treatment Technologies for Arsenic Removal

Technologies selected for Rounds 1, 2, and 2a demonstration included AM, iron removal (IR), coagulation/filtration (C/F), ion exchange (IX), reverse osmosis (RO), point-of-use (POU) RO, and system/process modification. Table 1-1 summarizes the locations, technologies, vendors, system flow-rates, and key source water quality parameters (including As, iron [Fe], and pH). Table 1-2 presents the number of sites for each technology. AM technology was demonstrated at 30 sites, including four with IR pretreatment. IR technology was demonstrated at 12 sites, including four with supplemental iron addition. C/F, IX, and RO technologies were demonstrated at three, two, and one sites, respectively. The Sunset Ranch Development site that demonstrated POU RO technology had nine under-the-sink RO units. The Oregon Institute of Technology (OIT) site classified under AM had three AM systems and eight POU AM units. The Lidgerwood site encompassed only system/process modifications. An overview of the technology selection and system design for the 12 Round 1 demonstration sites and the associated capital costs is provided in two EPA reports (Wang et al., 2004; Chen et al., 2004), which are posted on the EPA Web site at <http://www.epa.gov/ORD/NRMRL/arsenic/resource.htm>.

1.3 Project Objectives

The objective of the arsenic demonstration program was to conduct full-scale performance evaluations of treatment technologies for arsenic removal from drinking water supplies. The specific objectives were to:

- Evaluate the performance of the arsenic removal technologies for use on small systems.
- Determine the required system operation and maintenance (O&M) and operator skill levels.
- Characterize process residuals produced by the technologies.
- Determine the capital and O&M cost of the technologies.

This report summarizes the performance of the AdEdge system at the Geneseo Hills Subdivision in Geneseo, IL from May 8, 2008, through July 30, 2010. The types of data collected included system operation, water quality (both across the treatment train and in the distribution system), residuals, and capital and O&M costs.

**Table 1-1. Summary of Rounds 1, 2, and 2a Arsenic Removal Demonstration
Locations, Technologies, and Source Water Quality**

Demonstration Location	Site Name	Technology (Media)	Vendor	Design Flowrate (gpm)	Source Water Quality		
					As (µg/L)	Fe (µg/L)	pH (S.U.)
Northeast/Ohio							
Carmel, ME	Carmel Elementary School	RO	Norlen’s Water	1,200 gpd	21	<25	7.9
Wales, ME	Springbrook Mobile Home Park	AM (A/I Complex)	ATS	14	38 ^(a)	<25	8.6
Bow, NH	White Rock Water Company	AM (G2)	ADI	70 ^(b)	39	<25	7.7
Goffstown, NH	Orchard Highlands Subdivision	AM (E33)	AdEdge	10	33	<25	6.9
Rollinsford, NH	Rollinsford Water and Sewer District	AM (E33)	AdEdge	100	36 ^(a)	46	8.2
Dummerston, VT	Charette Mobile Home Park	AM (A/I Complex)	ATS	22	30	<25	7.9
Houghton, NY ^(c)	Town of Caneadea	IR (Macrolite)	Kinetico	550	27 ^(a)	1,806 ^(d)	7.6
Woodstock, CT	Woodstock Middle School	AM (Adsorbsia)	Siemens	17	21	<25	7.7
Pomfret, CT	Seely-Brown Village	AM (ArsenX ^{np})	SolmeteX	15	25	<25	7.3
Felton, DE	Town of Felton	C/F (Macrolite)	Kinetico	375	30 ^(a)	48	8.2
Stevensville, MD	Queen Anne’s County	AM (E33)	STS	300	19 ^(a)	270 ^(d)	7.3
Conneaut Lake, PA	Conneaut Lake Park	IR (Greensand Plus) with ID	AdEdge	250	28 ^(a)	157 ^(d)	8.0
Buckeye Lake, OH	Buckeye Lake Head Start Building	AM (ARM 200)	Kinetico	10	15 ^(a)	1,312 ^(d)	7.6
Springfield, OH	Chateau Estates Mobile Home Park	IR & AM (E33)	AdEdge	250 ^(e)	25 ^(a)	1,615 ^(d)	7.3
Great Lakes/Interior Plains							
Brown City, MI	City of Brown City	AM (E33)	STS	640	14 ^(a)	127 ^(d)	7.3
Pentwater, MI	Village of Pentwater	IR (Macrolite) with ID	Kinetico	400	13 ^(a)	466 ^(d)	6.9
Sandusky, MI	City of Sandusky	IR (Aeralater)	Siemens	340 ^(e)	16 ^(a)	1,387 ^(d)	6.9
Delavan, WI	Vintage on the Ponds	IR (Macrolite)	Kinetico	40	20 ^(a)	1,499 ^(d)	7.5
Goshen, IN	Clinton Christian School	IR & AM (E33)	AdEdge	25	29 ^(a)	810 ^(d)	7.4
Fountain City, IN	Northeastern Elementary School	IR (G2)	US Water	60	27 ^(a)	1,547 ^(d)	7.5
Waynesville, IL	Village of Waynesville	IR (Greensand Plus)	Peerless	96	32 ^(a)	2,543 ^(d)	7.1
Geneseo Hills, IL	Geneseo Hills Subdivision	AM (E33)	AdEdge	200	25 ^(a)	248 ^(d)	7.4
Greenville, WI	Town of Greenville	IR (Macrolite)	Kinetico	375	17 ^(a)	7,827 ^(d)	7.3
Climax, MN	City of Climax	IR (Macrolite) with ID	Kinetico	140	39 ^(a)	546 ^(d)	7.4
Sabin, MN	City of Sabin	IR (Macrolite)	Kinetico	250	34 ^(a)	1,470 ^(d)	7.3
Sauk Centre, MN	Big Sauk Lake Mobile Home Park	IR (Macrolite)	Kinetico	20	25 ^(a)	3,078 ^(d)	7.1
Stewart, MN	City of Stewart	IR &AM (E33)	AdEdge	250	42 ^(a)	1,344 ^(d)	7.7
Lidgerwood, ND	City of Lidgerwood	Process Modification	Kinetico	250	146 ^(a)	1,325 ^(d)	7.2
Lead, SD	Terry Trojan Water District	AM (ArsenX ^{np})	SolmeteX	75	24	<25	7.3
Midwest/Southwest							
Willard, UT	Hot Springs Mobile Home Park	IR & AM (Adsorbsia)	Filter Tech	30	15.4 ^(a)	332 ^(d)	7.5
Arnaudville, LA	United Water Systems	IR (Macrolite)	Kinetico	770 ^(e)	35 ^(a)	2,068 ^(d)	7.0
Alvin, TX	Oak Manor Municipal Utility District	AM (E33)	STS	150	19 ^(a)	95	7.8
Bruni, TX	Webb Consolidated Independent School District	AM (E33)	AdEdge	40	56 ^(a)	<25	8.0

**Table 1-1. Summary of Rounds 1, 2, and 2a Arsenic Removal Demonstration
Locations, Technologies, and Source Water Quality (Continued)**

Demonstration Location	Site Name	Technology (Media)	Vendor	Design Flowrate (gpm)	Source Water Quality		
					As (µg/L)	Fe (µg/L)	pH (S.U.)
Wellman, TX	City of Wellman	AM (E33)	AdEdge	100	45	<25	7.7
Anthony, NM	Desert Sands Mutual Domestic Water Consumers Association	AM (E33)	STS	320	23 ^(a)	39	7.7
Nambe Pueblo, NM	Nambe Pueblo Tribe	AM (E33)	AdEdge	145	33	<25	8.5
Taos, NM	Town of Taos	AM (E33)	STS	450	14	59	9.5
Rimrock, AZ	Arizona Water Company	AM (E33)	AdEdge	90 ^(b)	50	170	7.2
Tohono O'odham Nation, AZ	Tohono O'odham Utility Authority	AM (E33)	AdEdge	50	32	<25	8.2
Valley Vista, AZ	Arizona Water Company	AM (AAFS50/ARM 200)	Kinetico	37	41	<25	7.8
Far West							
Three Forks, MT	City of Three Forks	C/F (Macrolite)	Kinetico	250	64	<25	7.5
Fruitland, ID	City of Fruitland	IX (A300E)	Kinetico	250	44	<25	7.4
Homedale, ID	Sunset Ranch Development	POU RO ^(f)	Kinetico	75 gpd	52	134	7.5
Okanogan, WA	City of Okanogan	C/F (Electromedia-I)	Filtronics	750	18	69 ^(d)	8.0
Klamath Falls, OR	Oregon Institute of Technology	POE AM (Adsorbsia/ARM 200/ArsenX ^{np}) and POU AM (ARM 200) ^(g)	Kinetico	60/60/30	33	<25	7.9
Vale, OR	City of Vale	IX (Arsenex II)	Kinetico	525	17	<25	7.5
Reno, NV	South Truckee Meadows General Improvement District	AM (GFH)	Siemens	350	39	<25	7.4
Susanville, CA	Richmond School District	AM (A/I Complex)	ATS	12	37 ^(a)	125	7.5
Lake Isabella, CA	Upper Bodfish Well CH2-A	AM (HIX)	VEETech	50	35	125	7.5
Tehachapi, CA	Golden Hills Community Service District	AM (Isolux)	MEI	150	15	<25	6.9

AM = adsorptive media process; C/F = coagulation/filtration; HIX = hybrid ion exchanger; IR = iron removal; IR with ID = iron removal with iron addition; IX = ion exchange process; RO = reverse osmosis

ATS = Aquatic Treatment Systems; MEI = Magnesium Elektron, Inc.; STS = Severn Trent Services

(a) Arsenic existing mostly as As(III).

(b) Design flowrate reduced by 50% due to system reconfiguration from parallel to series operation.

(c) Selected originally to replace Village of Lyman, NE site, which withdrew from program in June 2006; withdrew from program in 2007 and replaced with a home system in Lewisburg, OH.

(d) Iron existing mostly as Fe(II).

(e) Facilities upgraded systems in Springfield, OH from 150 to 250 gpm, Sandusky, MI from 210 to 340 gpm, and Arnaudville, LA from 385 to 770 gpm.

(f) Including nine residential units.

(g) Including eight under-the-sink units.

Table 1-2. Number of Demonstration Sites Under Each Arsenic Removal Technology

Technologies	Number of Sites
Adsorptive Media ^(a)	26
Adsorptive Media with Iron Removal Pretreatment	4
Iron Removal (Oxidation/Filtration)	8
Iron Removal with Supplemental Iron Addition	4
Coagulation/Filtration	3
Ion Exchange	2
Reverse Osmosis	1
Point-of-use Reverse Osmosis ^(b)	1
System/Process Modifications	1

(a) OIT site at Klamath Falls, OR had three AM systems and eight POU AM units.

(b) Including nine under-the-sink RO units.

2.0 SUMMARY AND CONCLUSIONS

Based on the information collected during performance evaluation from May 8, 2008, through July 30, 2010, the following summary and conclusions were made relating to the overall objectives of the treatment technology demonstration study.

Performance of the arsenic removal technology for use on small systems:

- The parallel system at a design flowrate of 200 gpm adequately met the water demand of the Subdivision. Throughout the demonstration period, system instantaneous flowrates averaged 32 gpm, with only four instances having recorded flowrates of over 100 gpm. The peak demand occurred at 156 gpm excluding the 188 gpm that occurred during a water main break.
- Chlorine effectively oxidized soluble As(III) to soluble As(V), decreasing its concentrations from an average of 14.3 µg/L in Well No. 5 water to 0.6 µg/L after two hydropneumatic (hydro)/contact tanks.
- Chlorine also was effective in oxidizing soluble iron (359 µg/L [on average]), precipitating all soluble iron to iron solids. Co-precipitation and/or adsorption were presumed to be the responsible processes for the formation of 7.3 µg/L of arsenic laden iron particles.
- Settling of iron solids occurred in the two hydro/contact tanks, resulting in a 37% concentration reduction in total iron. The corresponding concentration reduction in total arsenic was less significant, amounting to only 0.4 µg/L (on average). Settling of iron solids was due, in part, to a long residence time (i.e., 11 hr based on an average on-demand flowrate of 32 gpm) experienced in the hydro/contact tanks.
- AD-33 was effective in removing total arsenic, reducing its concentrations to <3.3 µg/L throughout the demonstration period. Removal was achieved via soluble As(V) adsorption and particulate arsenic filtration. Before the end of the performance evaluation study, 33,158,000 gal (or 45,230 bed volumes [BV]) of water had been treated, equivalent to about 70% of the vendor-estimated media life.
- Backwash was useful for removing solids accumulating in the media beds. The effectiveness of backwash in restoring pressure drop across the adsorption vessels was not obvious because uncharacteristically low pressure differential (i.e., 0 lb/in² [psi]) was recorded throughout the entire demonstration period.
- Distribution system water contained less arsenic and iron after system startup. On average, the respective levels were reduced from 18.1 to 4.4 µg/L for arsenic and from 272 to 85 µg/L for iron. The reduced concentrations, although low, were still higher than those measured in the system effluent, suggesting redissolution and/or resuspension of some arsenic and iron in the distribution system.
- Average lead concentrations at two Lead and Copper Rule (LCR) sampling locations were reduced from 2.9 µg/L before system startup to 1.3 µg/L after system startup. Average copper concentrations at the two LCR locations were reduced from 946 to 670 µg/L. Before system startup, two copper (Cu) exceedances over the 1,300-µg/L action level were noted at one LCR location.

Required system O&M and operator's skill levels:

- Although the adsorption system itself did not require much operator attention, operation of the chlorine addition system, manual backwash, and backwash reclaim system (especially bag filters) did. The operator was well versed for system troubleshooting and repairs.

- For normal operations, the operator spent approximately 20 min during each visit to perform visual inspections and record system operational parameters.

Process residuals produced by the technology:

- The only process residual produced from system operation was backwash solids, which were transferred from the backwash holding tanks to a 550-gal sludge holding tank for temporary storage. Approximately 250 gal of sludge was accumulating in the holding tank; final disposal did not occur during the performance evaluation study.
- During each backwash event, approximately 8.2 lb of solids in 3,915-gal of wastewater were discharged into a backwash holding tank. The solids were composed of approximately 0.04 lb of arsenic, 2.2 lb of iron, and 0.02 lb of manganese.

Cost-effectiveness of the technology:

- The capital investment for the system was \$139,149, including \$101,290 (or 73%) for equipment, \$19,545 (or 14%) for site engineering, and \$18,314 (or 13%) for installation, shakedown, and startup.
- The unit capital cost was \$696/gpm (or \$0.48 gal/day [gpd]) based on a 200-gpm design capacity.
- The incremental O&M cost was \$0.05/1,000 gal for labor plus an undetermined amount for media replacement.

3.0 MATERIALS AND METHODS

3.1 General Project Approach

Following the predemonstration activities summarized in Table 3-1, the performance evaluation study of the AdEdge arsenic removal treatment system began on May 8, 2008, and ended on July 30, 2010. Table 3-2 summarizes the types of data collected and considered as part of the treatment technology evaluation process. The overall system performance was based on its ability to consistently remove arsenic to below the target MCL of 10 µg/L through the collection of water samples across the treatment train, as described in the Study Plan (Battelle, 2008). The reliability of the system was evaluated by tracking the unscheduled system downtime and frequency and extent of repair and replacement. The plant operator recorded unscheduled downtime and repair information on a Repair and Maintenance Log Sheet.

Table 3-1. Predemonstration Study Activities and Completion Dates

Activity	Date
Initial Site Visit & Introductory Meeting Held	December 6, 2006
Technology Selection Meeting Held	July 12, 2007
Project Planning Meeting Held	October 3, 2007
Draft Letter of Understanding Issued	October 22, 2007
Final Letter of Understanding Issued	October 26, 2007
Request for Quotation Issued to Vendor	November 2, 2007
Initial Vendor Quotation Received by Battelle	November 19, 2007
Final Vendor Quotation Received by Battelle	January 16, 2008
Purchase Order Completed and Signed	January 21, 2008
Initial Engineering Package Submitted to IL EPA	February 5, 2008
Final Engineering Package Submitted to IL EPA	March 13, 2008
Permit Issued by IL EPA	March 17, 2008
Equipment Arrived at Site	March 28, 2008
System Installation and Shakedown Completed	April 22, 2008
Final Study Plan Issued	May 2, 2008
Performance Evaluation Begun	May 18, 2008

IL EPA = Illinois Environmental Protection Agency

The O&M and operator skill requirements were evaluated based on a combination of quantitative data and qualitative considerations, including the need for pre- and/or post-treatment, level of system automation, extent of preventative maintenance activities, frequency of chemical and/or media handling and inventory, and general knowledge needed for relevant chemical processes and related health and safety practices. The staffing requirements for the system operation were recorded on an Operator Labor Hour Log Sheet.

The quantity of aqueous and solid residuals generated was estimated by tracking the volume of backwash wastewater produced during each backwash cycle. Backwash wastewater and solids were sampled and analyzed for chemical characteristics.

Table 3-2. Evaluation Objectives and Supporting Data Collection Activities

Evaluation Objective	Data Collection
Performance	-Ability to consistently meet 10 µg/L of arsenic in treated water
Reliability	-Unscheduled system downtime -Frequency and extent of repairs including a description of problems, materials and supplies needed, and associated labor and cost
System O&M and Operator Skill Requirements	-Pre- and post-treatment requirements -Level of automation for system operation and data collection -Staffing requirements including number of operators and laborers -Task analysis of preventative maintenance including number, frequency, and complexity of tasks -Chemical handling and inventory requirements -General knowledge needed for relevant chemical processes and health and safety practices
Residual Management	-Quantity and characteristics of aqueous and solid residuals generated by system operation
System Cost	-Capital cost for equipment, engineering, and installation -O&M cost for media replacement and disposal, electrical usage, and labor

The cost of the system was evaluated based on the capital cost per gpm (or gal/day [gpd]) of design capacity and the O&M cost per 1,000 gal of water treated. This task required tracking the capital cost for equipment, engineering, and installation, as well as the O&M cost for media replacement and disposal, chemical consumption, electrical usage, and labor.

3.2 System O&M and Cost Data Collection

The plant operator performed weekly and monthly system O&M and data collection according to instructions provided by the vendor and Battelle. Approximately three times per week, the plant operator recorded system operational data, including pressure, flowrate, totalizer, and hour meter readings on a Daily System Operation Log Sheet, and conducted visual inspections to ensure normal system operations. If any problem occurred, the plant operator contacted the Battelle Study Lead, who determined if the vendor should be contacted for troubleshooting. The plant operator recorded all relevant information, including the problem encountered, course of actions taken, materials and supplies used, and associated cost and labor incurred, on a Repair and Maintenance Log Sheet. Approximately twice per month, the plant operator measured free and total chlorine, temperature, pH, dissolved oxygen (DO), and oxidation-reduction potential (ORP) and recorded the results on a Weekly Onsite Water Quality Parameters Log Sheet. Approximately once per month, the operator backwashed the system and all relevant measurements were recorded on a Backwash Log Sheet.

The capital cost for the arsenic removal system consisted of the cost for equipment, site engineering, and system installation. The O&M cost consisted of the cost for media replacement and spent media disposal, electrical usage, and labor. Electricity consumption was determined from utility bills. Labor for various activities, such as routine system O&M, troubleshooting and repairs, and demonstration-related work, was tracked using an Operator Labor Hour Log Sheet. The routine system O&M included activities such as completing field logs, performing system inspections, and others as recommended by the vendor. The labor for demonstration-related work, including activities such as performing field measurements, collecting and shipping samples, and communicating with the Battelle Study Lead and the vendor, was recorded, but not used for the cost analysis.

Table 3-3. Sampling Schedule and Analytes

Sample Type	Sampling Locations^(a)	No. of Sampling Locations	Frequency	Analytes	Sampling Date
Source Water	Well No. 5	1	Once during initial site visit	Onsite: pH, temperature, DO, and ORP Offsite: As (total and soluble), As(III), As(V), Fe (total and soluble), Mn (total and soluble), Sb (total and soluble), V, Na, Ca, Mg, NH ₃ , NO ₃ , NO ₂ , Cl, F, SO ₄ , SiO ₂ , P, TDS, TOC, turbidity, and alkalinity	12/06/06
Treatment Plant Water	IN, AC, TT for “Speciation Sampling”	3	1 st Week of 4-Week Cycle ^(b)	Onsite: pH, temperature, DO, ORP, and Cl ₂ (free and total) ^(c) Offsite: As (total and soluble), As(III), As(V), Fe (total and soluble), Mn (total and soluble), Ca, Mg, F, NO ₃ , NH ₃ , SO ₄ , SiO ₂ , P, TOC, turbidity, and alkalinity	See Appendix B
	IN, AC, TA, TB for “Regular Sampling”	4	3 rd Week of 4-Week Cycle	Onsite: pH, temperature, DO, ORP, and Cl ₂ (free and total) ^(c) Offsite: As (total), Fe (total), Mn (total), NH ₃ , SiO ₂ , P (total), turbidity, and alkalinity	See Appendix B
Distribution Water	Two LCR Residences and Storage Tank #2	3	Monthly ^(d)	pH, alkalinity, As (total), Fe (total), Mn (total), Cu, Pb, and Cl ₂ (free and total) ^(e)	See Table 4-12
Backwash Wastewater	Backwash Discharge Line (BW)	2	Monthly ^(g)	pH, TDS, TSS, As (total and soluble), Fe (total and soluble), and Mn (total and soluble)	See Table 4-10
Backwash Solids	Wastewater Containers	2	Twice	As, Ba, Ca, Fe, Mg, Mn, P, and Si	11/18/08, 04/22/09
Backwash Sludge	Backwash Sludge Holding Tank	1	Once	As, Ba, Ca, Fe, Mg, Mn, P, and Si	06/24/10
Distribution Solids	Fire Hydrant	2 ^(f)	Once	As, Ba, Ca, Fe, Mg, Mn, P, and Si	04/21/10

Table 3-3. Sampling Schedule and Analytes (Continued)

- (a) Abbreviations corresponding to sample locations shown in Figure 4-3: IN = at wellhead, AC = after chlorination, TA/TB = after Vessel A/B, TT = total combined effluent, and BW = backwash discharge line.
 - (b) Starting on August 25, 2009, only monthly speciation samples collected and analyzed for onsite water quality parameters, As (total and soluble), As (III), As (V), Fe (total and soluble), Mn (total and soluble), NH₃, P, and TOC.
 - (c) Free and total chlorine not measured at IN sampling location.
 - (d) Four baseline sampling events performed during March 2008 prior to system startup; sampling discontinued after 07/22/09.
 - (e) Free and total chlorine measured onsite only during baseline sampling in March 2008.
 - (f) Fire hydrant flush samples collected from four locations but only two produced sufficient amounts of solids for analysis.
 - (g) Sampling discontinued after 10/21/09.
- LCR = Lead and Copper Rule, TDS = total dissolved solids, TOC = total organic carbon, TSS = total suspended solids

3.3 Sample Collection Procedures and Schedules

To evaluate system performance, samples were collected at the wellhead, across the treatment train, during adsorption vessel backwash, and from the distribution system. Table 3-3 presents sampling schedules and analytes measured during each sampling event. Specific sampling requirements for analytical methods, sample volumes, containers, preservation, and holding times are presented in Table 4-1 of the EPA-endorsed Quality Assurance Project Plan (QAPP) (Battelle, 2007). The procedure for arsenic speciation is described in Appendix A of the QAPP.

3.3.1 Source Water. During the initial site visit on December 6, 2006, one set of source water samples from Well No. 5 was collected and speciated using an arsenic speciation kit (see Section 3.4.1). The sample tap was flushed for several minutes before sampling and special care was taken to avoid agitation, which might cause unwanted oxidation. Analytes for the source water samples are listed in Table 3-3.

3.3.2 Treatment Plant Water. The Study Plan called for speciation and regular sampling on the first and third weeks of each four-week cycle, respectively, for onsite and offsite analyses. For speciation sampling, samples were collected at the wellhead (IN), after chlorination (AC), and after effluent from Vessels A and B combined (TT), speciated, and analyzed for the analytes listed under “speciation sampling” in Table 3-3. For regular sampling, samples were collected at IN, AC, after Vessel A (TA), and after Vessel B (TB) and analyzed for the analytes listed under “regular sampling” in Table 3-3.

Actual sampling performed during the performance evaluation study mostly followed the schedules described in the Study Plan, but with the following exceptions:

- Speciation sampling did not begin until July 22, 2008, about two months into the performance evaluation study. During the May 18 and July 1, 2008, sampling events, samples were analyzed for all analytes listed under “speciation sampling” except soluble arsenic, iron, and manganese. Sampling frequency varied from one to four weeks before July 22, 2008.
- From July 22, 2008, through July 22, 2009, sampling alternated between speciation and regular sampling at a frequency of one to three weeks.
- Starting on August 25, 2009, only monthly speciation sampling was performed, with the exception of June 2010 when two speciation sampling events took place. Samples were analyzed for onsite water quality parameters, total and soluble arsenic, iron, and manganese, As(III), As(V), NH₃, P, and TOC.

3.3.3 Backwash Wastewater and Solids. The plant operator collected backwash wastewater samples from each adsorption vessel on a monthly basis through October 21, 2009. Over the duration of backwash for each vessel, a side stream of backwash wastewater was directed from the tap on the backwash water discharge line to a clean, 32-gal plastic container at approximately 1 gpm. After the contents in the container were thoroughly mixed, two aliquots were collected for pH, total dissolved solids (TDS), total suspended solids (TSS), and total metals analyses. Another aliquot was collected and filtered with 0.45- μ m disc filters for soluble metals analysis. Analytes for backwash wastewater samples are listed in Table 3-3.

On November 18, 2008 and April 22, 2009, the contents in the 32-gal plastic container were allowed to settle and the supernatant was carefully siphoned using a piece of plastic tubing to avoid agitation of settled solids in the container. The remaining solids/water mixture was then transferred to a 1-gal plastic jar for shipment to Battelle. After solids in the jar were settled and the supernatant was carefully decanted, one aliquot of the solids/water mixture was air dried before being acid-digested and analyzed for the metals listed in Table 3-3.

In addition to the backwash solids sampling, a sludge sample was collected by EPA from a backwash sludge holding tank on June 24, 2010. As part of the backwash recycling system (see Section 4.2.2), the tank was used to collect and air dry backwash solids from the backwash recycling tank prior to disposal. The backwash sludge sample was analyzed for the metals listed in Table 3-3.

3.3.4 Spent Media. The media in the two adsorption vessels were not replaced during the performance evaluation study; therefore, no spent media was produced as residual solids.

3.3.5 Distribution System Water. Water samples were collected from within the distribution system to determine the impact of the treatment system on water chemistry, specifically the arsenic, lead, and copper levels, in the distribution system. Prior to system startup during March 2008, four baseline distribution system water samples were collected from two residences that were part of the historic sampling network under LCR and Storage Tank #2. Although not in the LCR network, Storage Tank #2 was included due to limited availability of other LCR residences within the subdivision. Following system startup, distribution system sampling continued on a monthly basis at the same three locations through July 22, 2009. Analytes for distribution system water samples are shown in Table 3-3.

The operator and homeowners collected samples following an instruction sheet developed according to the *Lead and Copper Monitoring and Reporting Guidance for Public Water Systems* (EPA, 2002). For the two residence locations, all samples were collected by the respective homeowners from a cold-water faucet that had not been used for at least 6 hr to ensure that stagnant water was sampled. The dates and times of last water usage before sampling and of actual sample collection were recorded for calculations of the stagnation time. Samples from Storage #2 were collected by the operator. Because this sampling location served as a large water main and was continually flushed, there was no stagnation time associated with this location.

3.3.6 Fire Hydrant Flush. On April 21, 2010, fire hydrant flush samples were collected by the operator from four fire hydrants located on Deer Path Court, Prairie Dawn Drive, Melody Lane, and Longview Drive within the Subdivision. Each sample was collected in a 1-gal plastic jar when high levels of solids were being flushed from the hydrant. After solids in the jar settled and the supernatant was carefully decanted, one aliquot of solids/water mixtures was air dried before being acid-digested and analyzed for the metals listed in Table 3-3. Although four fire hydrant flush samples were collected, only two located at Deer Path Court and Prairie Dawn Drive produced a sufficient amount of solids for analysis.

3.4 Sampling Logistics

3.4.1 Preparation of Arsenic Speciation Kits. The arsenic field speciation method used an anion exchange resin column to separate the soluble arsenic species, As(V) and As(III) (Edwards et al., 1998). Resin columns were prepared in batches at Battelle laboratories in accordance with the procedures detailed in Appendix A of the EPA-endorsed QAPP (Battelle, 2007).

3.4.2 Preparation of Sample Coolers. For each sampling event, a sample cooler was prepared with the appropriate number and type of sample bottles, disc filters, and/or speciation kits. All sample bottles were new and contained appropriate preservatives. Each sample bottle was affixed with a pre-printed, colored-coded, waterproof label consisting of the sample identification (ID), date and time of sample collection, collector's name, site location, sample destination, analysis required, and preservative. The sample ID consisted of a two-letter code for the demonstration site, the sampling date, a two-letter code for a specific sampling location, and a one-letter code designating the arsenic speciation bottle (if necessary). The sampling locations at the treatment plant were color-coded for easy identification. The labeled bottles were separated by sampling location, placed in zip-lock bags, and packed into the cooler.

In addition, all sampling- and shipping-related materials, such as disposable gloves, sampling instructions, chain-of-custody forms, prepaid/pre-addressed FedEx air bills, and bubble wrap, were placed in each cooler. The chain-of-custody forms and air bills were completed except for the operator's signature and the sample dates and times. After preparation, the sample cooler was sent to the site via FedEx for the following week's sampling event.

3.4.3 Sample Shipping and Handling. After sample collection, samples for off-site analyses were packed carefully in the original coolers with wet ice and shipped back to Battelle. Upon receipt, the sample custodian checked sample IDs against the chain-of-custody forms and verified that all samples indicated on the forms were included and intact. Discrepancies noted by the sample custodian were addressed with the plant operator by the Battelle Study Lead. The shipment and receipt of all coolers by Battelle were recorded on a cooler tracking log.

Samples for metal analyses were stored at Battelle's inductively coupled plasma-mass spectrometry (ICP-MS) Laboratory. Samples for other water quality analyses were packed in separate coolers and picked up by couriers from American Analytical Laboratories (AAL) in Columbus, OH and Belmont Labs in Englewood, OH, which were under contract with Battelle for this demonstration study. The chain-of-custody forms remained with the samples from the time of preparation through analysis and final disposition. All samples were archived by the appropriate laboratories for the respective duration of the required hold time and disposed of properly thereafter.

3.5 Analytical Procedures

The analytical procedures described in detail in Section 4.0 of the EPA-endorsed QAPP (Battelle, 2007) were followed by Battelle's ICP-MS laboratory, AAL, and Belmont Labs. Laboratory quality assurance/quality control (QA/QC) of all methods followed the prescribed guidelines. Data quality in terms of precision, accuracy, method detection limits (MDLs), and completeness met the criteria established in the QAPP (i.e., relative percent difference [RPD] of 20%, percent recovery of 80 to 120%, and completeness of 80%). The QA data associated with each analyte will be presented and evaluated in a QA/QC Summary Report to be prepared under separate cover upon completion of the Arsenic Demonstration Project.

On-site field measurements of pH, temperature, DO, and ORP were conducted by the plant operator using a VWR Symphony SP90M5 Handheld Multimeter, which was calibrated for pH and DO prior to use following the procedures provided in the user's manual. The ORP probe also was checked for accuracy

by measuring the ORP of a standard solution and comparing it to the expected value. The plant operator collected a water sample in a clean, plastic beaker and placed the Symphony SP90M5 probe in the beaker until a stable value was obtained for each parameter. The plant operator also performed free and total chlorine measurements using Hach chlorine test kits following the user's manual.

4.0 RESULTS AND DISCUSSION

4.1 Pre-existing Facility Description and Treatment System Infrastructure

Located at 10 N. Meadowbrook Dr., Geneseo, IL, the Geneseo Hills facility is a community water system serving a population of 480 people in the Geneseo Hills Subdivision. The facility was supplied by two wells, Wells No. 4 and No. 5. Before June 2006, Well No. 4 was the main supply well. Because it could not adequately meet the Subdivision's average daily demand of approximately 40,600 gpd, a new well, Well No. 5, was drilled and completed in June 2006. Since then, Well No. 4 has been used only as a backup well.

Wells No. 4 and 5 are located approximately 25 ft northwest and 100 ft south, respectively, of the pump house. Well No. 4 was 6-in in diameter and 525 ft deep, equipped with a 10-horsepower (hp) submersible pump rated for 90 gpm at 138 ft H₂O or 60 psi of total dynamic head (TDH). The top of the pump was set at 325 ft below ground surface (bgs) and the static water level was 117 ft bgs. Well No. 5 was 10-in in diameter and 525 ft deep, equipped with a 25-hp Grundfos submersible pump rated for 250 gpm at 360 ft H₂O or 156 psi of TDH. The top of the pump was set at 330 ft bgs. With its larger capacity, Well No. 5 typically operated 6 to 8 hr/day.

The pre-existing 63 ft × 30 ft × 12 ft pump house provided a shelter for wellhead piping, two chemical addition systems, and various instrumentation, including pressure gauges and totalizers (see Figure 4-1). Prior to this demonstration project, the treatment included chlorination and fluoridation with chemicals injected in the water from both wells combined. Chlorination was accomplished using a 12.5% sodium hypochlorite (NaOCl) solution to maintain a target dosage of 1.9 to 2.1 mg/L (as Cl₂) and a target total chlorine residual level of 1.2 mg/L (as Cl₂) in the distribution system. Fluoridation was carried out using a 23% hydrofluorosilic acid (H₂SiF₆) solution, diluted 30:1 (by volume), for a target dosage of 1.08 mg/L. Each chemical addition system consisted of a 125-gal high-density polyethylene (HDPE) chemical day tank and a 22 gpd-rated Stenner peristaltic pump synchronized with the well pump. The chemical pump settings were 55% stroke and 100% speed for chlorination and 80 to 90% stroke and 100% speed for fluoridation.

The water system has two pressure and two storage tanks with a total capacity of 35,000 gal. One 9,000- and one 12,000-gal aboveground hydropneumatic (hydro) tank are housed in the facility (Figure 4-2). A set of low/high pressure setpoints at 40 and 60 psi, respectively, controls the on/off of the well pumps. One 5,700- (6-ft in diameter) and 8,300-gal (8-ft in diameter) underground storage tank are located 700 and 1,500 ft, respectively, downstream of the pump house and serve essentially as large water mains. The only means of wastewater disposal available in the Subdivision is septic tanks at the individual homes.

4.1.1 Source Water Quality. Samples of Well No. 5 water were collected on December 6, 2006, when a Battelle staff member traveled with EPA to the site to attend an introductory meeting for this demonstration study. Table 4-1 presents the results and compares them to the data provided by EPA for Well No. 4 water collected on March 6, 2006, as well as the data provided by IL EPA for Well No. 5 water (both raw and finished water) collected historically between June 8 through October 10, 2006. Only limited historic data existed for Well No. 5 water because it was not drilled until June 2006. Well No. 5 raw water data collected by Battelle indicate slightly higher levels of total arsenic, iron, and manganese than those provided by IL EPA.

The treatment train for the demonstration project includes prechlorination and adsorption. Factors such as arsenic and iron speciation and concentration, pH, natural organic matter, ammonia, and competing anions such as silica and phosphorus can affect system performance. The results of source water assessment and implications for water treatment are discussed below.



Figure 4-1. Piping in Pump House at Geneseo Hills Subdivision Facility



Figure 4-2. 12,000-gal Hydropneumatic Tank at Geneseo Hills Subdivision Facility

Table 4-1. Geneseo Hills Subdivision Water Quality Data

Parameter	Unit	EPA Data	Battelle Data	IL EPA Historical Data	
		Well No. 4 Raw	Well No. 5 Raw	Well No. 5 Raw	Well No. 5 Finished
Date		03/06/06	12/06/06	06/08/06	09/12/06–10/10/06
pH	S.U.	NA	7.1	7.4	NA
Temperature	°C	NA	10.4	NA	NA
DO	mg/L	NA	1.5	NA	NA
ORP	mV	NA	89	NA	NA
Total Alkalinity (as CaCO ₃)	mg/L	NA	407	367	NA
Total Hardness (as CaCO ₃)	mg/L	290	341	344	NA
Turbidity	NTU	NA	1.9	2.6	NA
TDS	mg/L	NA	548	352	NA
TOC	mg/L	NA	1.8	NA	NA
Nitrate (as N)	mg/L	<0.02	<0.05	<0.07	NA
Nitrite (as N)	mg/L	<0.01	<0.05	NA	NA
Ammonia (as N)	mg/L	1.5	1.2	NA	NA
Chloride	mg/L	<5.0	<1.0	1.8	NA
Fluoride	mg/L	NA	0.3	0.3	1.0
Sulfate	mg/L	0.1	<1.0	<0.3	<10.0
Silica (as SiO ₂)	mg/L	18.1	20.3	NA	NA
Orthophosphate (as PO ₄)	mg/L	0.3	NA	NA	NA
P (as PO ₄)	mg/L	0.6	0.1	NA	NA
Al (total)	µg/L	<25	NA	NA	NA
As (total)	µg/L	13.0	24.9	18.4	14.0–17.0
As (soluble)	µg/L	NA	19.6	NA	NA
As (particulate)	µg/L	NA	5.3	NA	NA
As(III)	µg/L	NA	17.5	NA	NA
As(V)	µg/L	NA	2.1	NA	NA
Fe (total)	µg/L	243	248	179	120
Fe (soluble)	µg/L	NA	227	NA	NA
Mn (total)	µg/L	2.9	18.1	<7.0	<15
Mn (soluble)	µg/L	NA	8.3	NA	NA
Sb (total)	µg/L	<25	<0.1	NA	<2.0
Sb (soluble)	µg/L	NA	<0.1	NA	NA
V (total)	µg/L	NA	<0.1	NA	NA
Na (total)	mg/L	9.4	10.4	11.5	14.0
Ca (total)	mg/L	66.6	81.7	76.7	NA
Mg (total)	mg/L	30.1	33.3	37.0	NA

Arsenic. Total arsenic concentrations in water from Well No. 5 ranged from 18.4 to 24.9 µg/L. Based on the Battelle sampling results of December 6, 2006, out of 24.9 µg/L of total arsenic, 17.5 µg/L (or 70.3%) existed as soluble As(III) and 2.1 µg/L (8.4%) existed as soluble As(V). Therefore, As(III) was the predominate species and chlorine or another form of oxidant would be necessary to oxidize soluble As(III) to soluble As(V) for more effective arsenic removal via adsorption. In Well No. 4 water, the total arsenic concentration was lower at 13 µg/L, but still greater than the 10 µg/L MCL.

Iron and Manganese. Total iron concentrations in Well No. 5 water ranged from 179 to 248 µg/L, existing almost entirely as soluble iron. In Well No. 4 water, the total iron concentration was measured at 243 µg/L. Since these values were below the secondary maximum contaminant level (SMCL) of 300 µg/L for iron, this water was amenable to adsorption processes. Overall, adsorption processes are most effective with low influent iron levels (i.e., below SMCL) due to the potential for iron fouling of the AM. Conversely, the presence of soluble iron in raw water may help remove soluble arsenic once an oxidant, such as chlorine, is introduced into raw water. Chlorination prior to the AM will oxidize and precipitate iron, enabling removal of arsenic-laden iron solids via filtration through the media.

The total manganese concentration in water from Well No. 5 was 18.1 µg/L with 47% existing as soluble manganese. The total manganese concentration in source water for Well No. 4 was lower at 2.9 µg/L. Manganese at these levels was not expected to impact system performance.

Ammonia and TOC. Wells No. 4 and/or No. 5 source water contained 1.2 to 1.5 mg/L of ammonia (NH₃ [as N]) and 1.8 mg/L of TOC. The presence of ammonia in source water consumes chlorine and forms chloramines. As noted above, the facility maintains a target total chlorine residual level of 1.2 mg/L (as Cl₂) in the distribution system. To reach this level, 0.2 mg/L of chlorine (as Cl₂) would be needed to react with reducing species such as As(III), Fe(II), and Mn(II), and 1.2 to 1.5 mg/L of chlorine (as Cl₂) needed to react with NH₃ (as N) to form chloramines.

The presence of TOC can increase chlorine demand and form disinfection byproducts (DBPs) such as total trihalomethanes (TTHM) and haloacetic acids (HAA5). Results of historic sampling indicate that TTHM and HAA5 concentrations were below their respective MCL of 80 and 60 µg/L. From October 1999 through June 2008, the maximum TTHM concentration detected was 2.2 µg/L (as chloroform) and the maximum HAA5 concentration detected was 2.7 µg/L, based on historic data collected by IL EPA.

Competing Anions. Arsenic removal by adsorption processes potentially can be influenced by competing anions such as silica and phosphorus. The presence of 20.3 mg/L of silica (as SiO₂) and 0.1 mg/L of phosphorus (as PO₄) potentially can affect arsenic adsorption.

Other Water Quality Parameters. Data collected by Battelle indicate a neutral pH of 7.1 for Well No. 5, which is within the target range of 5.5 to 8.5 for arsenic removal via AM. Total hardness concentrations ranged from 341 to 344 mg/L (as CaCO₃), indicating that the water was a hard water. Total alkalinity ranged from 367 to 407 mg/L (as CaCO₃); turbidity from 1.9 to 2.6 nephelometric turbidity units (NTU); TDS from 352 to 548 mg/L. All other measured analytes were below detection limits and/or low enough not to adversely affect arsenic adsorption.

4.1.2 Treated Water Quality. In addition to source water data, Table 4-1 presents historic treated water quality data provided by IL EPA from September 12 through October 10, 2006. Total arsenic concentrations after chlorination and fluoridation ranged from 14.0 to 17.0 µg/L, which were lower than IL EPA and Battelle's raw water total arsenic results of 18.4 and 24.9 µg/L, respectively. Total iron concentrations in the treated water was 120 µg/L, which also was lower than IL EPA and Battelle's raw water results of 179 and 248 µg/L, respectively. Lower arsenic and iron levels in the chlorinated water were expected because arsenic was attached to iron solids to form arsenic-laden particles, some of which could settle in the distribution system. Results of other water quality parameters were similar to those of raw water. Treated water samples were not collected by Battelle or EPA at the time of source water sampling.

4.1.3 Distribution System. The distribution system for the Geneseo Hills Subdivision has 155 service connections. Based on the information provided by the facility, the infrastructure for the water distribution system is constructed of 1¼- to 4-in polyvinyl chloride (PVC) pipe. Piping within the homes is primarily copper; no lead pipe or lead solder is present in the homes.

The Geneseo Hills Subdivision samples the distribution system water periodically for several parameters: monthly for bacteria and fluoride; quarterly for arsenic; once every year for nitrate/nitrite; once every three years for inorganics, volatile organic compounds (VOCs), DBPs (including TTHM and HAA5), and pesticides; once every three to six years for radionuclides; and once every six years for lead and copper per LCR. Results for these sampling activities are posted on the IL EPA Drinking Water Watch Web portal (IL EPA, 2011).

4.2 Treatment Process Description

The arsenic package unit (APU) marketed by AdEdge is a fixed-bed, down-flow AM system used for small water systems in the flow range of 5 to 300 gpm. The system uses Bayoxide E33 media (branded as AD-33 by AdEdge), an iron-based AM developed by Lanxess (formerly Bayer AG) and marketed by Severn Trent Services (STS) for arsenic removal from drinking water supplies. Table 4-2 presents the media's physical and chemical properties. Before 2010, the media was available in both granular and pelletized forms, with the pelletized media 25% denser than the granular media (35 vs. 28 lb/ft³). (The adsorptive capacities of both media were similar on a per pound basis). The pelletized media was designed for more robust applications such as frequent backwashes, but because of lack of apparent benefits, STS had stopped recommending the use of this type of media for arsenic removal in 2010. E33 is delivered in a dry crystalline form and listed by NSF International (NSF) under Standard 61 for use in drinking water applications. The granular media was used at the Geneseo Hills Subdivision.


As groundwater is pumped through the fixed-bed pressure vessels, dissolved arsenic is adsorbed onto the media, thus reducing the total arsenic concentration in the treated water. When the media reaches its capacity (effluent water greater than 10 µg/L of total arsenic), the spent media is removed and disposed of as a non-hazardous waste after passing the EPA Toxicity Characteristic Leaching Procedure (TCLP) test. The media life depends upon the arsenic speciation and concentration, pH, concentrations of competing anions, and empty bed contact time (EBCT).

As noted above, chlorination was used to provide chlorine residuals in the distribution system. Because soluble As(III) was the predominant species, chlorine also was used to oxidize soluble As(III) to soluble As(V) for more effective arsenic removal by E33 media. pH values of source water ranged from 7.1 to 7.4; therefore, pH adjustment was not required.

The treatment system installed at the Geneseo Hills Subdivision consisted of two pressure vessels, configured in parallel to meet IL EPA's rule-of-thumb system flowrate requirement per peak use rate of 165 gpm. The system was located downgradient of the two hydro tanks for "on-demand" operations to avoid using a larger system for the specified well flowrate of 250 gpm. Table 4-3 presents key system design parameters of the treatment system. Figure 4-3 is a generalized flow diagram of the system including sampling locations and parameters analyzed during the demonstration study. The major components of the treatment system include:

- **Intake.** Raw water was pumped from Well No. 5, chlorinated, and fed to the two pre-existing hydro tanks. The well pump turned on and off at 40 and 60 psi, respectively, in the two hydro tanks. Well pump flowrates and throughput were tracked by a 4-in turbine flow meter/totalizer (Water Specialties Corp.).

Table 4-2. Physical and Chemical Properties of Bayoxide E33 Granular Media^(a)

<i>Physical Properties</i>	
Parameter	Value
Physical Form and Appearance	Amber, dry granular media 
Matrix	Iron oxide composite
Bulk Density (lb/ft ³)	28.1
BET Area (m ² /g)	142
Attrition (%)	0.3
Moisture Content (%)	<15% by weight
Base Polymer	Macroporous polystyrene
Particle Size Distribution (U.S. standard mesh)	10 × 35
Crystal Size (Å)	70
Crystal Phase	α-FeOOH
<i>Chemical Analysis</i>	
Constituents	Weight (%)
FeOOH	90.1
CaO	0.27
MgO	1.00
MnO	0.11
SO ₃	0.13
Na ₂ O	0.12
TiO ₂	0.11
SiO ₂	0.06
Al ₂ O ₃	0.05
P ₂ O ₅	0.02
Cl	0.01

(a) Provided by Bayer AG.

BET = Brunauer, Emmett, and Teller

- Prechlorination.** The pre-existing chlorine addition system was used to inject 12.5% NaOCl directly into incoming raw water. The injection point was located approximately 10 ft downstream of the raw water sampling tap (i.e., IN), but upstream of the two hydro tanks. The chlorine addition system consisted of a 22 gpd-rated Stenner peristaltic pump and a 125-gal HDPE chemical day tank, which was replaced by a 50-gal HDPE tank in November 2009 due to leaks from the 125-gal tank (Figure 4-4). Chlorine consumption was monitored three times a week through measurements of solution levels in the chemical day tank. Chlorine, which oxidized soluble As(III) to soluble As(V), was added to achieve a target total chlorine residual level of 1.2 mg/L (as Cl₂) in the distribution system. Chlorine residual levels were monitored after the two hydro tanks (AC) and the two adsorption vessels (TA and TB).
- Hydro/Contact Tanks.** After chlorination, well water flowed into the two hydro tanks with 9,000- and 12,000-gal storage capacities. Because these tanks were arranged in series, they provided a total of 11 hr contact time based on an average instantaneous system flowrate of 32 gpm (see Section 4.4). The contact time facilitated the formation of settleable arsenic-laden particles, causing concentrations of total arsenic and total iron to decrease in the water exiting the tanks.

Table 4-3. Design Specifications of Arsenic Removal System

Parameter	Value	Remarks
<i>Pretreatment</i>		
Chlorine Dosage (mg/L [as Cl ₂])	2.0	Using 12.5% NaOCl
<i>Adsorption Vessels</i>		
Vessel Size (in)	54 D × 60 H Side Shell	–
Cross-Sectional Area (ft ² /vessel)	15.9	–
No. of Vessels	2	–
Configuration	Parallel	–
<i>Adsorptive Media</i>		
Media Type	AD-33	Granular
Media Weight (lb)	2,744	1,372 lb/vessel
Media Volume (ft ³)	98	49 ft ³ /vessel
Media Bed Depth (in)	37.0	–
<i>Hydro/Contact Tanks</i>		
No. of Tanks	2	–
Configuration	Series	–
Volume of Tanks (gal)	12,000/9,000	–
Contact Time (hr)	1.8	~11 hr based on average instantaneous system flowrate of 32 gpm
<i>Service</i>		
Design Flowrate (gpm)	200	100 gpm/vessel
Hydraulic Loading Rate (gpm/ft ²)	6.3	1.0 gpm/ft ² based on average instantaneous system flowrate of 32 gpm
EBCT (min)	3.7	22.9 min based on average instantaneous system flowrate of 32 gpm
Estimated Working Capacity (BV)	65,000	Vendor-estimated BV to 10 µg/L total arsenic breakthrough from vessels
Throughput to Breakthrough (gal)	47,645,000	1 BV = 733 gal
Average Use Rate (gal/day)	40,600	Provided by operator
Estimated Media Life (month)	39	–
<i>Backwash</i>		
Pressure Differential Setpoint (psi)	10	All backwash events initiated manually during performance evaluation study
Backwash Rate (gpm/ft ²)	9.1	At 145 gpm
Backwash Frequency	Varying	For both Vessels A and B
Backwash Flowrate (gpm/vessel)	145	–
Backwash Duration (min/vessel)	12	–
Fast Rinse Flowrate (gpm/vessel)	145	–
Fast Rinse Duration (min/vessel)	1.5	–
Wastewater Production (gal/vessel)	1,958	–

- Adsorption.** The treatment system consisted of two 54-in × 60-in, 100 psi-rated, skid-mounted carbon-steel vessels configured in parallel (Figure 4-5). Each vessel contained 10 ft³ of gravel underbedding overlain by 49 ft³ of granular AD-33 media. At a design flowrate of 100 gpm for each vessel, the hydraulic loading rate was 6.3 gpm/ft² and EBCT was 3.7 min. On-demand flowrates and throughput were tracked by a SeaMetrics EX81P electromagnetic flow meter/totalizer, installed at the inlet side of each adsorption vessel.

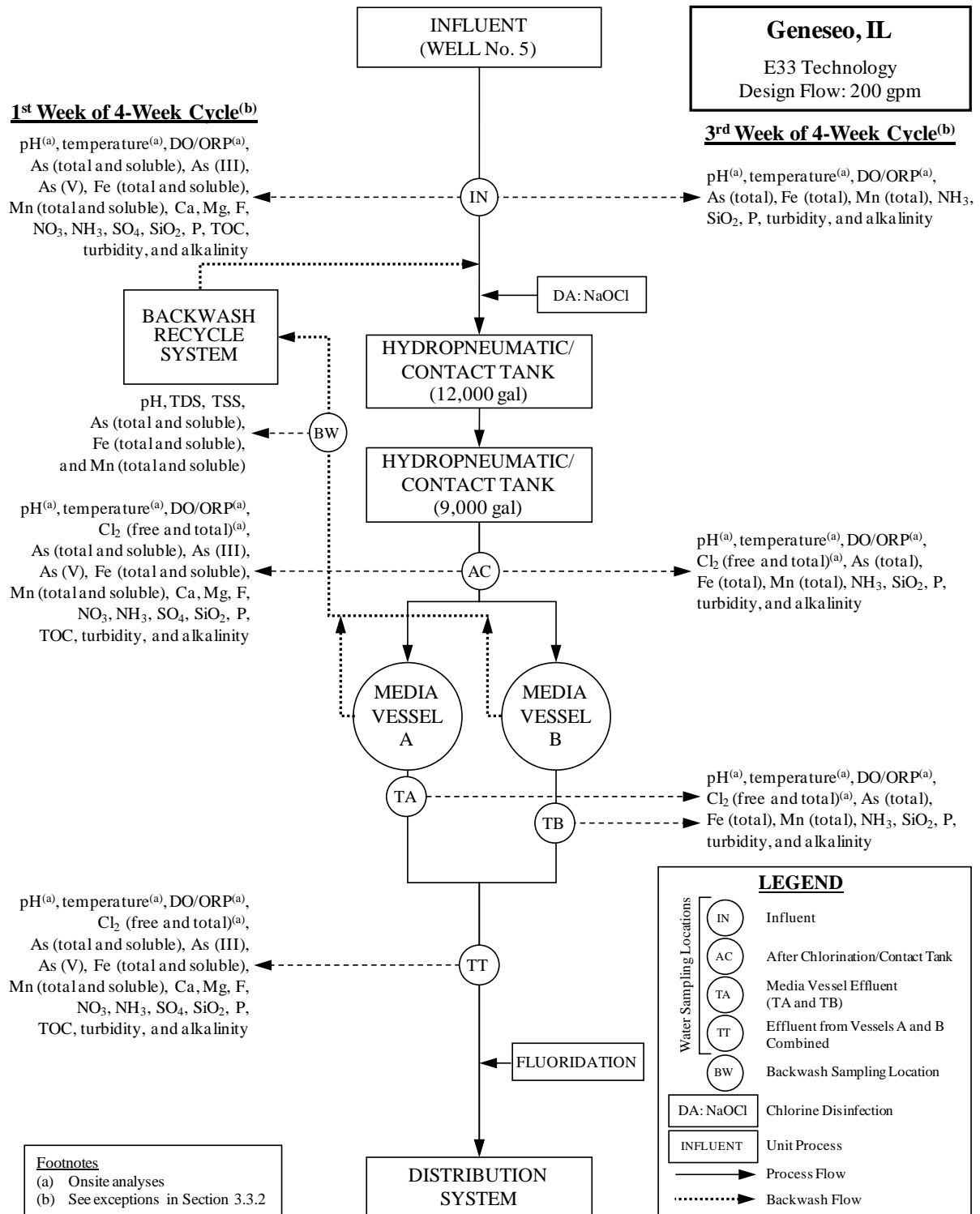


Figure 4-3. Process Flow Diagram and Sampling Locations



Figure 4-4. Chlorine Addition System at Geneseo Hills Subdivision Facility
(50 gal Tank on left replaced pre-existing 125-gal tank on right)

Each pressure vessel was interconnected with schedule 80 PVC piping and five electrically actuated butterfly valves, which made up the valve tree as shown in Figure 4-5. In addition, the system had two manual lug-style butterfly valves to divert incoming flow into each vessel and two manual diaphragm valves on the backwash line. Each valve operated independently and the electrically actuated butterfly valves were controlled by an Allen-Bradley 1500 Micrologix programmable logic controller (PLC) with a PanelView Plus 600 Color touch interface screen.

- **Backwash.** The vendor recommended that the treatment system be backwashed every 30 to 60 days to remove particulates accumulating in the media beds and to “fluff” the media beds to prevent channeling. The recommended backwash flowrate was 145 gpm to achieve a backwash rate of 9.1 gpm/ft². Backwash flowrates and throughput were tracked by a SeaMetrics EX81P flow meter/totalizer installed on the backwash wastewater discharge line.

Backwash could be initiated manually or automatically based on differential pressure (Δp) measured across individual pressure vessels, time, or volume of water treated. During the demonstration study, backwash was initiated only manually to facilitate backwash observation and wastewater sampling. Backwash was set to last for 13.5 min/vessel, including 12 min for an upflow wash and 1.5 min for a downflow rinse. Water from the two hydro tanks was used for backwash. Approximately 1,958 gal of wastewater was generated



Figure 4-5. AdEdge Arsenic Treatment System at Geneseo Hills Subdivision Facility

per vessel, or 3,915 gal per event. During the demonstration study, a total of 20 backwash events took place, with frequencies spanning from one backwash per 7 days to one backwash per 86 days.

- Backwash Recycling System.** Because there was no sewer to receive backwash wastewater and because backwash wastewater could not be used for irrigation purposes per IL EPA, the liquid fraction was recycled to the head of the treatment train upstream of the chlorine injection point and the two hydro tanks. The backwash recycling system consisted of a 316-stainless steel bag filter assembly (containing two filter bags in parallel configuration); a 102-in diameter, 5,000-gal HDPE backwash holding tank; a 48-in diameter, 550-gal HDPE sludge holding tank; a GPI vertical, multistage, centrifugal pump rated for 15.4 gpm at 114 ft-H₂O TDH; and associated piping/valves and controls (Figures 4-6 and 4-7).

During backwash, wastewater was directed from the adsorption vessels through the bag filters to the backwash holding tank. After the contents were allowed to settle for a minimum of 24 hr, supernatant was pumped from an intake point located 18-in above the ground level on the backwash holding tank. The recycled flowrate was maintained at approximately 12 gpm so that the ratio between the recycled flow and service flow did not exceed 10%. The reclaim pump was activated only when the water level in the backwash holding tank was above the low-level switch at 18 in above the ground level and the well pump was on. The backwash holding tank was not equipped with a high-level switch. Instead, a 2-in diameter overflow pipe was installed at the top of the tank to direct any overages to the outside of the treatment building. The sludge accumulating in the backwash holding tank was transferred to the sludge holding tank using a 26-gpm pump for air drying and eventual disposal.

Because the bag filter assembly was located before the backwash holding tank, filter bags with nominal pore sizes of 25-, 50-, and even 100- μm , at times, were clogged soon after backwash had begun (e.g., 3 min). To continue backwashing, the operator had to replace filter bags as many as three times during a backwash event. To reduce the filter bag usage, a decision was made to move the bag filter assembly after the backwash holding tank so that the filter bags would filter only supernatant being recycled to the treatment system.

Periodically, the sludge in the bottom of the backwash holding tank was pumped to a sludge holding tank. The sludge, after some air drying, would then be sampled for the TCLP test prior to disposal. Figure 4-8 presents a conceptual process flow diagram of the treatment system and backwash recycling system.



Figure 4-6. Backwash Recycling System Components
(Clockwise from upper left: Bag Filter Assembly, Sludge Holding Tank, Backwash Holding Tank, and Reclaim Pump and Control)



Figure 4-7. Backwash Recycling System in Geneseo Hills Subdivision Facility

- Media Replacement.** Upon breakthrough of arsenic at 10 µg/L, the spent media is removed from the adsorption vessels using a shop vac and virgin media is loaded as done during initial media loading. Because total arsenic concentrations did not exceed the 10-µg/L MCL, media was not changed out during the performance evaluation study.

4.3 System Installation

Installation and shakedown of the treatment system was completed by AdEdge and its subcontractors on April 22, 2008. The following subsections summarize pre-demonstration activities, including permitting, building preparation, and system offloading, installation, shakedown, and startup.

4.3.1 Permitting. The engineering plan and permit application package was prepared by Missman, Stanley & Associates, an engineering subcontractor to AdEdge. The plan/package included a process flow diagram of the treatment system, mechanical drawings of the equipment, and a schematic of the equipment layout and was submitted to IL EPA on February 5, 2008. On March 6, 2008, IL EPA provided comments on the plan requesting information regarding (1) the depth of support gravel, (2) the depth of the media beds and effective size of the media, (3) the proposed piping layout, and (4) the recycled water flowrate. Missman, Stanley & Associates provided IL EPA with the requested information on March 13, 2008, and the final engineering plan was approved and the permit was issued by IL EPA on March 17, 2008.

4.3.2 Building Preparation. The meeting room of the existing treatment facility was modified by the Geneseo Hills Homeowners Association to house the arsenic treatment system. The height of the meeting room was extended by 5½ ft with the final dimensions of the room being 15.5 ft × 27 ft × 13 ft. A 10 ft × 10 ft area of concrete was reinforced to support the weight of the backwash holding tank and a 12 ft high × 10 ft wide roll-up door was installed where the door was previously located on the building. Figure 4-9 is a photograph of the modified building at Geneseo Hills Subdivision.

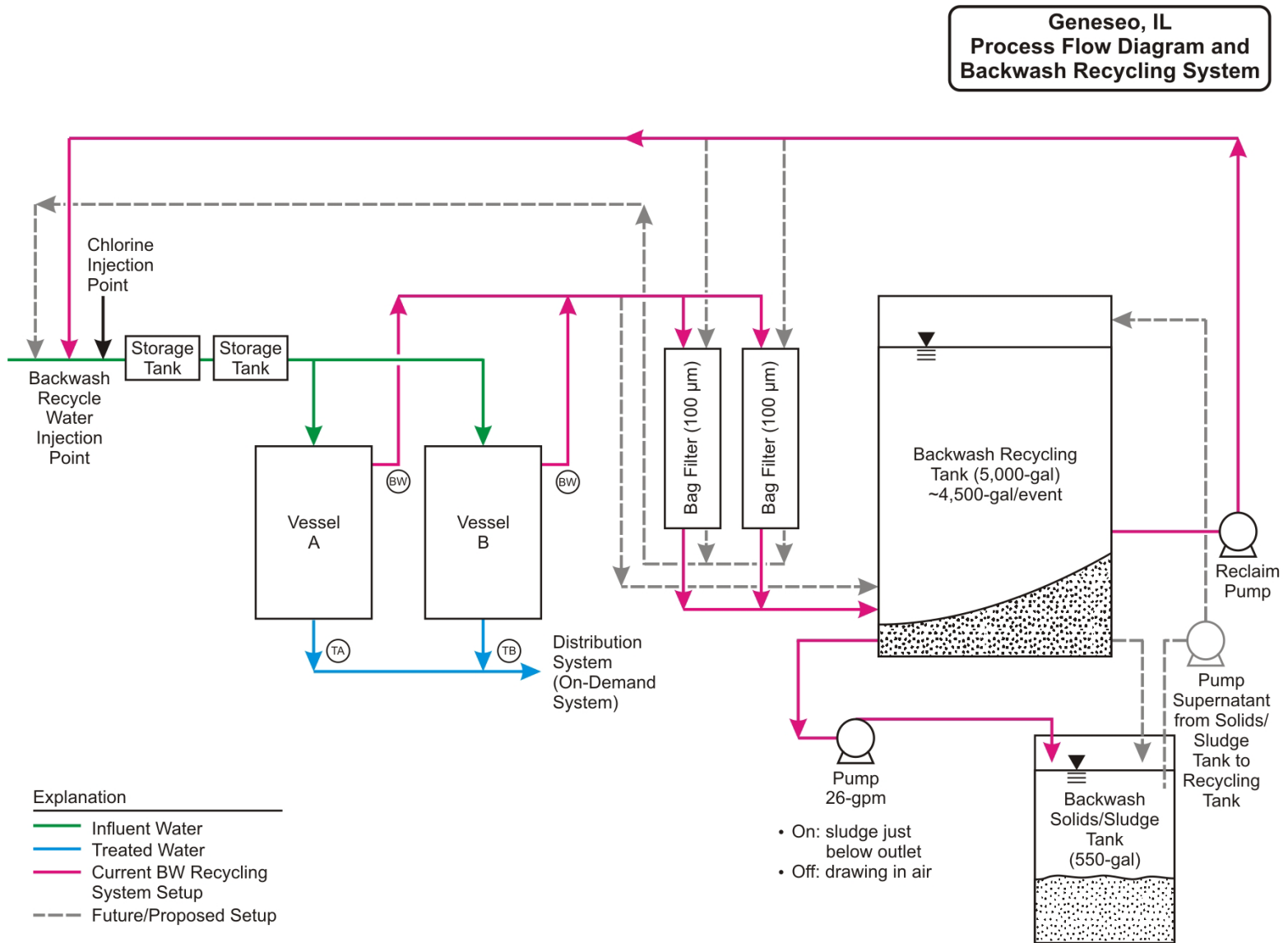


Figure 4-8. Process Flow Diagram and Backwash Recycling System



Figure 4-9. Modified Facility at Geneseo Hills Subdivision
(Clockwise from top left: Previous Meeting Room in Facility, Modified Facility After and Before Completion of Construction)

4.3.3 Installation, Shakedown, and Startup. The treatment system along with 17 5.9-ft³ containers of AD-33 media arrived at the site on March 28, 2008. Prior to delivery, the system was tested hydraulically to ensure integrity of all system components and establish a baseline pressure profile across the system. Results of factory testing at a forward flowrate of 42 to 146 gpm and no media in the adsorption vessels showed an inlet/outlet pressure of 22 to 48 psi and a Δp of 0 psi across each vessel, indicating no flow restriction through relevant system components.

System installation began immediately after system arrival. AdEdge and its contactor, Schmitt Plumbing-Heating, Inc. in Dixon, IL, performed all installation activities, including placing and anchoring the pressure vessel skid, connecting inlet/outlet plumbing at tie-ins, completing electrical wiring, assembling the backwash reclaim system, and making proper adjustments to the pre-existing chlorine addition system. Upon completion, follow-on installation activities began on April 10 and 11, 2008, and included (1) inspections of all plumbing and electrical connections, (2) hydraulic testing of the system without media in forward flow, and (3) gravel and media loading and backwashing along with freeboard measurements.

Without media in the vessels, the onsite hydraulic testing in forward flow indicated a pressure loss of only 2 psi across the system, Vessel A, and Vessel B, similar to the results obtained during the factory testing. The inlet and outlet pressure readings were 30 and 28 psi, respectively, across the system and for each vessel. During testing, the system reached a flowrate of 199 gpm (i.e., 99 gpm at Vessel A and 100 gpm at Vessel B), which was very close to the design flowrate of 200 gpm.

Afterwards, gravel and AD-33 media were loaded into each vessel half-filled with water. Table 4-4 presents freeboard measurement results. Based on the measurements before media backwash, 51.7 ft³ of media was loaded into each vessel, compared to the design value of 49 ft³ per vessel. After media backwash at 150 gpm for approximately 30 min, freeboards to the top of the media beds were measured

Table 4-4. Freeboard Measurements During System Installation

Freeboard Measurements ^(a)	Vessel A			Vessel B		
	Freeboard (in)	Bed Depth (in) ^(b)	Volume (ft ³)	Freeboard (in)	Bed Depth (in) ^(b)	Volume (ft ³)
<i>Before Backwash</i>						
To Top of Gravel Underbedding (in)	56	NA	NA	56	NA	NA
To Top of Media Bed (in)	17	39	51.7	17	39	51.7
<i>After Backwash</i>						
To Top of Media Bed (in)	19	37	49.0	18	38	50.4

(a) From vessel top sidewall welded seam.

(b) Calculated based on 60-in straight walled sides.

again and approximately 49.0 and 50.4 ft³ of media remained in Vessels A and B, respectively. For this performance evaluation study, the design value of 49 ft³ per vessel was used in BV calculations.

On April 21 and 22, 2008, the vendor completed additional shakedown activities, including (1) hydraulic testing in service and backwash mode, (2) PLC program review, (3) function testing of the entire system in automatic mode, and (4) bacteria testing. The vendor also provided operator training. On April 21, 2008, the treatment system was placed online by the operator for hydraulic and automatic function testing at a system flowrate of 85 gpm (by throttling a 3-in manual valve at the outlet of each vessel) to mimic on-demand operations. The flowrates measured at Vessels A and B were 43 and 42 gpm, respectively, indicating balanced flow. Δp readings across the system and each vessel were approximately 1 psi, which was lower than what would be anticipated from a media-loaded system. After passing the bacteria test on April 22, 2008, the system officially went online. The performance evaluation study began on May 8, 2008.

On July 22, 2008, two Battelle staff members were onsite to inspect the system and provide training to the operator for system sampling and operational data collection. As a result of system inspections, a punch-list (Table 4-5) was identified and forwarded to the vendor on July 28, 2008. The issues identified were resolved either by the vendor or the operator before August 5, 2008.

Table 4-5. System Punch-List Items

Item No.	Punch-List/ Operational Issues	Corrective Action(s) Taken	Resolution Date
1	Provide O&M manual to Battelle	A copy sent to Battelle	08/05/08
2	Re-examine design of backwash wastewater recycling system to ensure proper reclaim of wastewater	Recommendations to modify system design/operation sent to Battelle	08/05/08
3	Adjust valves (DV-113A and DV-113B) to limit maximum flow	No action required by vendor; operator adjusted valves to limit flow to 100 gpm per vessel	Between 04/23/08–07/21/08
4	Reconfigure/update system software to reset backwash totalizer (i.e., gallons treated since last backwash) after each backwash cycle	A new program chip sent to site by vendor	05/15/08

4.4 System Operation

4.4.1 Operational Parameters. System operational parameters recorded during the demonstration period are tabulated and attached as Appendix A; key parameters are summarized in Table 4-6. From May 8, 2008, through July 30, 2010, the system treated approximately 33,158,000 gal (or 45,230 BV) of water based on readings from a SeaMetrics EX81P electromagnetic flow meter/totalizer installed on each adsorption vessel. The well pump operated for a total of 2,147 hr. Daily run times ranged from 0.1 to 6.4 hr/day and averaged 2.6 hr/day. Because the hour meter was interlocked with Well No. 5 and because the system was operating on-demand, the pump run time was not representative of the treatment system run time. Based on the wellhead master flow meter/totalizer, Well No. 5 water was fed to the two hydro/contact tanks at an average flowrate of 220 gpm.

Due to on-demand operation, chlorinated water in the two hydro/contact tanks flowed through the adsorption vessels only when the distribution system called for treated water. On-demand flowrates were tracked by readings of a SeaMetrics EX81P electromagnetic flow meter/totalizer on each adsorption vessel. Figure 4-10 presents instantaneous flowrates for Vessels A and B and the system (i.e., sum of Vessels A and B readings). During the demonstration period, system instantaneous flowrates ranged from 0 to 188 gpm and averaged 32 gpm. System instantaneous flowrates were typically well below the design flowrate of 200 gpm with only four readings equal to or greater than 100 gpm. On October 30, 2009, uncharacteristically high flowrate readings (i.e., 86 and 102 gpm, the maximum values measured during the demonstration period) were registered by the flow meters due to a water main break underneath the treatment plant building. Once the leak was repaired, system instantaneous flowrates returned to typical levels.

Table 4-6. Summary of Operational System Parameters

Operational Parameter	Value		
Performance Period	05/08/08–07/30/10		
Well No. 5			
Total Operating Time (hr) ^(a)	2,147		
Average Daily Run Time (hr/day)	2.6 (0.1–6.4)		
Throughput at Wellhead (gal)	28,604,680		
Calculated Flowrate to Hydro/Contact Tanks (gpm) ^(b)	220 (68.3–458)		
Calculated NaOCl Dosage (mg/L [as Cl ₂]) ^(c)	6.6		
AD-33 Adsorption System			
	<u>Vessel A</u>	<u>Vessel B</u>	<u>Combined</u>
Throughput (gal)	16,401,436	16,756,827	33,158,263
Bed Volumes (BV)	44,749	45,719	45,234
Instantaneous Flowrate (gpm) ^(d)	15.8 (0–86)	16.3 (0–102)	32.0 (0–188)
Hydraulic Loading (gpm/ft ²)	1.0 (0–5.4)	1.0 (0–6.4)	NA
EBCT (min)	22.9 (≥4.3)	22.9 (≥3.6)	NA
Δp Across Adsorption Vessels/System (psi)	0–0	0–0	2 (1–19)
System Inlet/Outlet Pressure (psi)	52 (40–60)/50 (21–58)		

(a) Wellhead hour meter installed on 09/26/08; operating time from 05/08/08 to 09/25/08 estimated using that registered during same period in 2009 (i.e., 05/08/09 to 09/25/09).

(b) Data on 10/24/08, 04/04/09, 06/18/10, and 06/25/10 considered outliers and omitted from calculations.

(c) NaOCl dosage from 07/30/08, 08/25/08, 10/24/08, 04/04/09, 06/18/10, and 06/25/10 considered outliers and omitted from calculations.

(d) High flowrates at 86 and 102 gpm for Vessels A and B, respectively, caused by pipe break under treatment plant building.

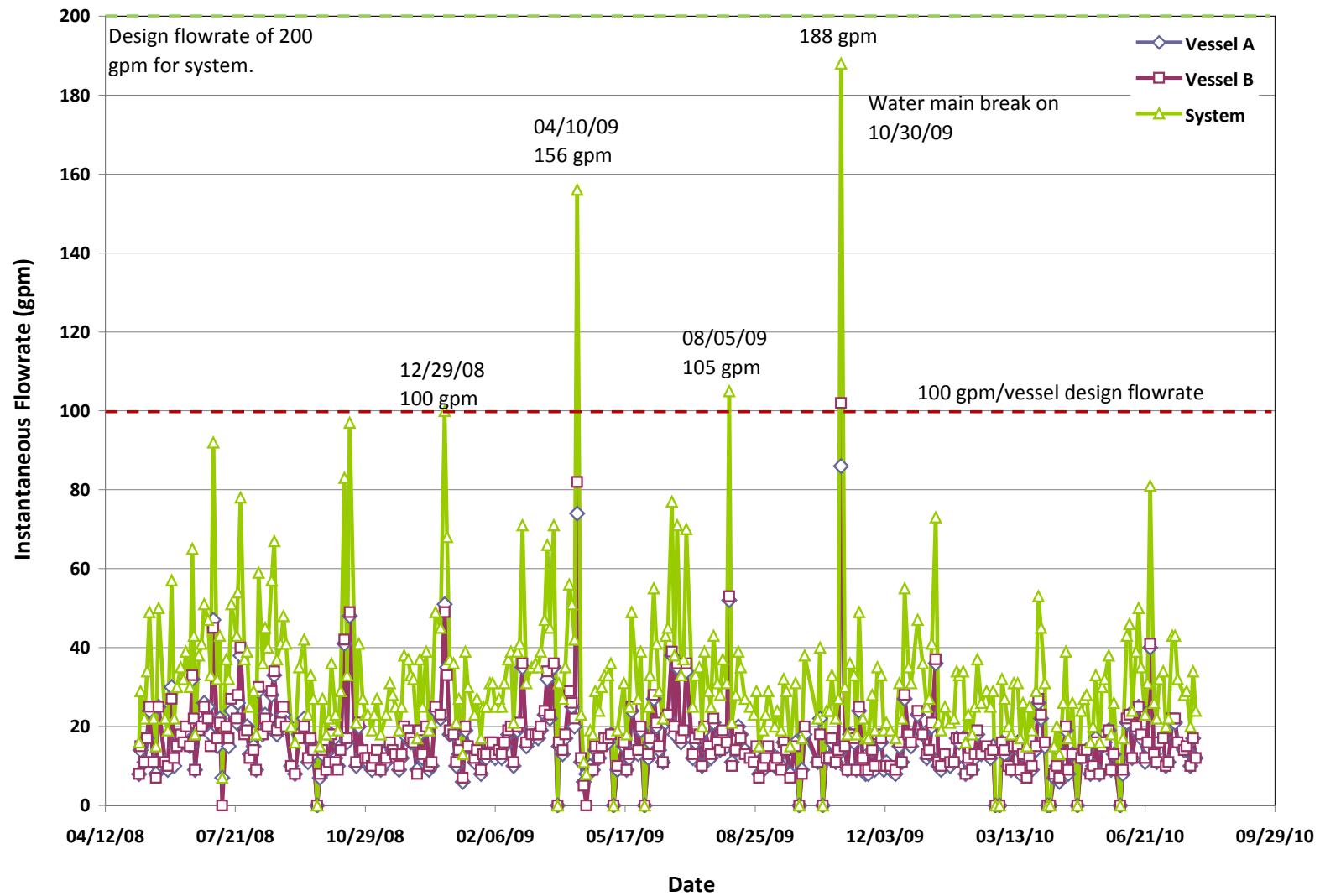


Figure 4-10. Instantaneous Flowrate Measurements from the Treatment System

Because the average instantaneous flowrate to each adsorption vessel was significantly lower (16 gpm) than the design value of 100 gpm, the average hydraulic loading rate was significantly lower (1.0 gpm/ft²) than the design value of 6.3 gpm/ft² and the average EBCT was significantly higher (22.9 min) than the design value of 3.7 min.

Throughout the demonstration period, pressure across the system was monitored with an inlet and outlet panel-mounted, pressure gauge with the capability to measure pressure from 0 to 100 psi. Δp across each adsorption vessel was monitored with a panel-mounted, piston-type differential pressure gauge with the capability to measure Δp from 0 to 30 psi. Throughout the demonstration period, Δp readings across Vessels A and B remained unchanged at 0 psi. These results were somewhat unexpected because a few psi pressure drop normally would be observed across a clean AD-33 bed and because an increase in pressure drop normally would be noticeable upon accumulation of solids in the bed. Pressure drop would return to the clean-bed level only after an adequate backwash. Δp readings across the system ranged from 1 to 19 psi and averaged 2 psi. The 19 psi reading was recorded on October 30, 2009, during the water main break mentioned above. Once the leak was repaired, Δp readings across the system returned to 2 psi throughout the remainder of the demonstration period. The low pressure drop across the system and the adsorption vessels was indicative of little flow restriction imposed by system components such as pipe, valves, top diffusers, and bottom laterals.

4.4.2 Chlorine Injection. As described in Section 4.2, 12.5% NaOCl solution was utilized to oxidize soluble As(III) to soluble As(V) and provide a target total chlorine residual level of 1.2 mg/L (as Cl₂) in the distribution system. During the demonstration period, the chlorine tank level was monitored approximately three times per week, along with other operational parameters, to determine the chlorine dosage. NaOCl dosages thus determined averaged 6.6 mg/L (as Cl₂), which is significantly higher than the design value of 2.0 mg/L (as Cl₂). As to be discussed in Section 4.5.1, an average of 2.4 mg/L of total chlorine (as Cl₂) was measured after the hydro/contact tanks and after the adsorption vessels (this residual level was 100% higher than the target level of 1.2 mg/L [as Cl₂]). Excluding the amount (~0.3 mg/L [as Cl₂]) that would be needed to oxidize reducing species, such as soluble As(III), soluble Fe(II), and soluble Mn(II), the amount unaccounted for would be 3.9 mg/L (as Cl₂) (i.e., $6.6 - 2.4 - 0.3 = 3.9$). It is possible that some chlorine was consumed by reacting with TOC (see Table 4-9). The NaOCl solution concentration (12.5%) also can be an issue due to chlorine self-destruction. As noted in Section 4.4.5, the operator ordered ten 15-gal containers every three to four months. NaOCl concentrations in some of the containers may not be at its full strength by the time it gets to be used.

4.4.3 Backwash. Although automatic backwash could be triggered by a Δp , a time, or a throughput setpoint, only manual backwashes were performed during the demonstration period. As shown in Table 4-7, Vessels A and B were backwashed 20 and 18 times, respectively. Vessel B was not backwashed on July 22 and August 25, 2008, due to clogging of filter bags during backwash. To avoid clogging, the nominal pore size of filter bags was increased from 25 to 50 μm and then to 100 μm (see more detailed discussion in Section 4.4.5). The vessels were backwashed once every 7 to 86 days (or once every 45 days on [average]). Different backwash frequencies do not appear to have impacted pressure drop across the E33 vessels (as evidenced by constant Δp readings at 0 psi throughout the study period) or caused leakage of iron particles through the vessels (as discussed in Section 4.4.5.1 under *Iron and Manganese*). The amount of wastewater produced per backwash event was recorded only twice on May 16 and 23, 2008, totaling 3,947 and 3,265 gal, respectively. The amount collected on May 16, 2008, was very close to the design value of 3,915 gal. Because of the lack of wastewater production data, it was assumed that 3,915 gal of wastewater was produced during each backwash event. Therefore, the total amount of wastewater produced would be 78,300 gal, with most being recycled to the head of the treatment train upstream. The remaining account was transferred to the sludge holding tank.

Table 4-7. Summary for System Backwash

Date	Duration Between Backwashes (day)	Amount of Wastewater Produced (gal)		Filter Bag Nominal Pore Size (µm)
		Vessel A	Vessel B	
05/16/08	-	2,000	1,947	25
05/23/08	7	1,667	1,598	25
07/22/08	60	1,368	NB	25
08/25/08	34	NC	NB	50, 100
10/08/08	44	NC	NC	100
11/19/08	42	NC	NC	100
12/17/08	288	NC	NC	100
01/21/09	35	NC	NC	100
02/18/09	28	NC	NC	100
03/18/09	28	NC	NC	100
04/22/09	35	NC	NC	100
05/20/09	28	NC	NC	100
06/24/09	35	NC	NC	100
07/22/09	28	NC	NC	100
08/26/09	35	NC	NC	100
09/30/09	35	NC	NC	100
10/21/09	21	NC	NC	100
01/15/10	86	NC	NC	100
03/24/10	68	NC	NC	100
06/0910	77	NC	NC	100

NC = data not collected; NB = not backwashed due to filter clogging

4.4.4 Residual Management. Because AD-33 media was not replaced during the demonstration period and because backwash wastewater was recycled, only sludge was produced and temporarily stored in the sludge holding tank for final disposal.

4.4.5 System/Operation Reliability and Simplicity. The only operational issue experienced was replacement of filter bags during system backwash. Because the bag filter assembly was located before the backwash holding tank, filter bags were clogged soon after the backwash had begun. To continue backwashing, the operator had to replace filter bags as many as three times during a backwash event. Initially, the system was fitted with 25-µm filter bags. On May 16, May 23, and July 22, 2008, 25-µm filter bags were used, but inlet pressure to the filter bags increased to 60 psi within 3 min and water stopped flowing through the filter bags once the inlet pressure reached 20 psi. Based on these observations, nominal pore sizes of filter bags were adjusted to 50 µm on August 25, 2008, and then to 100 µm on September 9 (backwashing attempted but not completed) and October 8, 2008. After successful testing on October 8, 2008, 100-µm filter bags continued to be used during 15 additional backwash events throughout the remainder of the demonstration period.

Follow-on discussions had been made with the vendor and operator to move the bag filter assembly to a location downstream of the backwash holding tank such that filter bags would filter only the recycled supernatant as opposed to solids-laden wastewater. The relocation, however, was not implemented before the end of the performance evaluation study.

The system O&M and operator skill requirements are discussed below in relation to pre- and post-treatment requirements, levels of system automation, operator skill requirements, preventative maintenance activities, and frequency of chemical/media handling and inventory requirements.

Pre- and Post-Treatment Requirements. The chlorination system, as discussed in Section 4.2 and shown in Figure 4-4, utilized a 12.5% NaOCl solution to oxidize soluble As(III) to soluble As(V) and reach a target free residual level of 1.2 mg/L (as Cl₂). The chlorination system did not require additional maintenance or skills, other than those required prior to the demonstration study. The operator monitored NaOCl solution consumption rates and residual chlorine levels approximately three times per week throughout the demonstration period. Post-treatment was not needed for this system.

System Automation. The system was fitted with controls for automatic backwash. The automated portion of the system did not require regular O&M; however, operator awareness and an ability to detect unusual system measurements were necessary when troubleshooting system automation failures. The chlorine addition system was interlocked with the operation of Well No. 5; thus, only requiring the operator to continue to refill the chemical day tank. The well pump turned on and off at 40 and 60 psi, respectively, of pressure in the two hydro tanks. The reclaim pump on the backwash recycling system was operating only when the water level in the backwash holding tank was above the low-level switch at 18 in above the ground level and when the well pump was on. The equipment vendor provided hands-on training and an O&M manual to the operator during system installation, shakedown, and startup (see Section 4.3.3).

Operator Skill Requirements. Under normal operating conditions, the skills required to operate the treatment system were minimal. Operator knowledge of the system limitations and typical operational parameters were critical in achieving system performance objectives. The operator was onsite typically three times per week and spent approximately 20 min during each visit to perform visual inspections and record system operational parameters on the daily log sheets. Other than routine activities, the operator's duties included monitoring and refilling the chlorine day tank as well as initiating manual backwash events (which may include changing filter bags on the backwash recycling system, if necessary).

Operator training began onsite with the equipment vendor during system installation, shakedown, and startup and with a thorough review of the system O&M manual. However, over the demonstration period, the operator found that invaluable system troubleshooting skills were gained through hands-on operational experience.

IL EPA requires that the operator of the treatment system at the Geneseo Hills Subdivision hold at least a Class B IL EPA drinking water operator certification. IL EPA drinking water operator certifications are classified from Class A through D with Class A being the highest and requiring the most education, experience, and training. Licensing eligibility requirements are based on education, experience, and related training and incrementally increase with each licensing level. Specifically, Class B requires a high school diploma or equivalent and three years of responsible experience in water supply operation.

Preventive Maintenance Activities. Preventive maintenance tasks included periodic checks of flow meters and pressure gauges and inspection of system piping and valves. The chlorine day tank and supply lines also were checked for leaks and adequate pressure. Typically, the operator performed these duties when onsite for routine activities approximately three times per week.

Chemical/Media Handling and Inventory Requirements. NaOCl was utilized to oxidize soluble As(III) to soluble As(V) prior to the two hydro tanks and provide a target total chlorine residual level of 1.2 mg/L (as Cl₂) in the distribution system. The operator continued to order 12.5% NaOCl solution throughout the

demonstration period as was done prior to installation of the treatment system (i.e., 10 15-gal containers from Brenntag Mid-South of Henderson, KY every three to four months).

4.5 System Performance

The performance of the arsenic treatment system was evaluated based on results of water samples collected across the treatment train, during media backwash, and from the distribution system.

4.5.1 Treatment Plant Sampling. The treatment plant water was sampled on 45 occasions including four duplicate and 25 speciation sampling events. A complete set of the results was tabulated and is included in Appendix B. Table 4-8 summarizes results of arsenic, iron, and manganese across the treatment train. Table 4-9 summarizes results of other water quality parameters. Figure 4-11 presents results of the 25 arsenic speciation events at the IN, AC, and TT locations. The results for the AC location from January 13, 2010, were not included in the figure because they looked as if chlorine had not been added during the sampling event (even though 0.9 mg/L of total chlorine [as Cl₂] was measured). Results of the treatment plant water sampling are discussed below.

Arsenic. As shown in Table 4-8, total arsenic concentrations in raw water (IN) ranged from 15.9 to 24.4 µg/L and averaged 19.6 µg/L. As stated in Section 4.1.1, soluble As(III) was the predominant species, with concentrations ranging from 11.4 to 17.1 µg/L and averaging 14.3 µg/L. Low levels of soluble As(V) and particulate arsenic also were present, averaging 3.5 and 1.3 µg/L, respectively.

The presence of As(III) as the predominant species is consistent with the relatively low DO and ORP measurements, which averaged 0.8 mg/L and -49.1 mV, respectively (see Table 4-9). After chlorination and the two hydro/contact tanks (AC), DO levels increased to an average of 1.6 mg/L and remained essentially unchanged after the adsorption vessels (TA/TB/TT). ORP readings increased significantly, as expected, to an average of 315 mV and, like DO, remained rather unchanged across the adsorption vessels. Measured total chlorine residual levels averaged 2.4, 2.5, 2.7, and 2.3 mg/L (as Cl₂) at the AC, TA, TB, and TT locations, respectively.

Chlorine reacted with ammonia in raw water, reducing its concentrations from an average of 1.3 (at IN) to 1.0 mg/L (as N) after the hydro/contact tanks and after the adsorption vessels. Based on the stoichiometric relationship between chlorine and ammonia, approximately 1.5 mg/L of chloramines (as Cl₂) would be produced. This amount was lower than the average value of 2.4 mg/L (as Cl₂) actually measured after the hydro/contact tanks and after the adsorption vessels.

After chlorination and the hydro/contact tanks, total arsenic concentrations decreased slightly to an average of 19.2 µg/L. Chlorine effectively oxidized soluble As(III) to soluble As(V), decreasing its concentrations from an average of 14.3 (at IN) to 0.6 µg/L (for a net decrease of 13.7 µg/L). The soluble As(V) formed either stayed as is or formed arsenic-laden solids (due to the presence of soluble iron in source water; see detailed discussions under *Iron and Manganese Subsection*), resulting in a net increase of 5.9 and 7.3 µg/L (on average) for soluble As(V) and particulate arsenic, respectively. The difference between the net decrease in soluble As(III) concentration (i.e., 13.7 µg/L) and the sum of the net increases in soluble As(V) and particulate arsenic concentrations (i.e., 13.2 µg/L) reflects the amount that might have settled in the hydro/contact tanks. As mentioned in Section 4.2, the hydro/contact tanks provided an average of 11-hr contact time at an average system flowrate of 32 gpm.

Table 4-8. Analytical Results for Arsenic, Iron, and Manganese

Parameter	Sample Location	Unit	Sample Count	Concentration			Standard Deviation
				Minimum	Maximum	Average	
As (total)	IN	µg/L	45	15.9	24.4	19.6	2.3
	AC ^(b)	µg/L	44	14.9	23.1	19.2	2.1
	TA	µg/L	20	<0.1	1.8	— ^(a)	— ^(a)
	TB ^(c)	µg/L	19	<0.1	2.5	— ^(a)	— ^(a)
	TT	µg/L	25	0.5	3.3	— ^(a)	— ^(a)
As (soluble)	IN	µg/L	25	16.1	21.4	17.8	1.2
	AC ^(b)	µg/L	24	6.9	12.8	10.0	1.5
	TT	µg/L	25	0.3	1.3	— ^(a)	— ^(a)
As (particulate)	IN	µg/L	25	<0.1	4.9	1.3	1.6
	AC ^(b)	µg/L	24	4.0	14.1	8.6	3.0
	TT	µg/L	25	<0.1	2.3	— ^(a)	— ^(a)
As (III)	IN	µg/L	25	11.4	17.1	14.3	1.3
	AC ^(b)	µg/L	24	0.3	1.0	0.6	0.2
	TT	µg/L	25	<0.1	1.0	— ^(a)	— ^(a)
As (V)	IN	µg/L	25	<0.1	6.9	3.5	1.4
	AC ^(b)	µg/L	24	6.3	12.4	9.4	1.5
	TT	µg/L	25	<0.1	0.9	— ^(a)	— ^(a)
Fe (total)	IN ^(d)	µg/L	45	85	1,329	554	277
	AC	µg/L	45	204	602	347	77
	TA	µg/L	20	<25	<25	<25	—
	TB ^(c)	µg/L	19	<25	50.7	<25	10.3
	TT ^(e)	µg/L	24	<25	83.7	<25	15.4
Fe (soluble)	IN ^(d)	µg/L	25	170	790	359	183
	AC ^(b)	µg/L	24	<25	66.5	<25	18.1
	TT	µg/L	25	<25	73.5	<25	12.7
Mn (total)	IN ^(d)	µg/L	45	4.4	19.9	8.0	3.2
	AC	µg/L	45	4.7	7.8	6.3	0.8
	TA	µg/L	20	0.4	8.2	6.3	1.9
	TB ^(c)	µg/L	20	0.3	8.6	6.4	2.3
	TT	µg/L	25	4.2	9.9	6.6	1.5
Mn (soluble)	IN ^(d)	µg/L	25	5.0	12.0	8.0	1.8
	AC	µg/L	25	4.5	6.9	5.6	0.7
	TT	µg/L	25	4.2	10.2	6.7	1.7

One-half of detection limit used for samples with concentrations less than detection limit for calculations.

- (a) Average and standard deviation calculations not meaningful due to arsenic breakthrough from adsorption vessels; see breakthrough curves in Figure 4-12 for total arsenic and Figure 4-11 for particulate arsenic, soluble As(III), and soluble As(V).
- (b) Data on 01/13/10 not used in statistical analysis due to abnormal results.
- (c) Data on 05/20/09 not used in statistical analysis due to abnormal results.
- (d) Soluble Fe/Mn concentrations in raw water significantly greater than respective total Fe/Mn concentrations on eight occasions (12/03/08, 01/07/09, 03/11/09, 11/18/09, 01/13/10, 02/10/10, 04/07/10, and 06/09/10 [see Appendix B]); values flipped for statistical analysis and Fe/Mn breakthrough curve plots (see Figures 4-13 and 4-14).
- (e) Data on 01/22/08 not used in statistical analysis due to abnormal result.

Table 4-9. Summary of Water Quality Parameter Sampling Results

Parameter	Sample Location	Unit	Sample Count	Concentration			Standard Deviation
				Minimum	Maximum	Average	
Alkalinity (as CaCO ₃)	IN ^(a)	mg/L	30	365	402	380	11.0
	AC ^(a)	mg/L	30	348	398	378	10.6
	TA ^(a)	mg/L	18	368	396	379	8.7
	TB ^(a)	mg/L	18	361	404	379	10.3
	TT	mg/L	12	368	396	380	9.5
Ammonia (as N)	IN	mg/L	45	1.0	1.6	1.3	0.1
	AC	mg/L	45	0.8	1.3	1.0	0.1
	TA	mg/L	20	0.8	1.3	1.0	0.1
	TB	mg/L	20	0.9	1.3	1.0	0.1
	TT	mg/L	25	0.9	1.2	1.0	0.1
Fluoride	IN	mg/L	14	0.2	0.4	0.3	0.0
	AC	mg/L	14	0.2	0.4	0.3	0.0
	TA	mg/L	2	0.3	0.4	0.4	0.0
	TB	mg/L	2	0.3	0.3	0.3	–
	TT	mg/L	12	0.2	0.9	0.6	0.3
Sulfate	IN	mg/L	14	<0.1	0.2	<0.1	0.0
	AC	mg/L	14	0.3	0.4	0.3	0.0
	TA	mg/L	2	0.3	0.3	0.3	–
	TB	mg/L	2	0.3	0.3	0.3	–
	TT	mg/L	12	0.3	0.4	0.3	0.0
Nitrate (as N)	IN	mg/L	14	<0.05	<0.05	<0.05	–
	AC	mg/L	14	<0.05	<0.05	<0.05	–
	TA	mg/L	2	<0.05	<0.05	<0.05	–
	TB	mg/L	2	<0.05	<0.05	<0.05	–
	TT	mg/L	12	<0.05	<0.05	<0.05	–
Phosphorus (as P)	IN ^(b)	µg/L	44	20.1	88.2	49.8	10.8
	AC ^(b)	µg/L	44	19.4	88.1	50.1	12.1
	TA	µg/L	20	<10	<10	– ^(c)	– ^(c)
	TB ^(b)	µg/L	19	<10	<10	– ^(c)	– ^(c)
	TT	µg/L	25	<10	19.8	– ^(c)	– ^(c)
Silica (as SiO ₂)	IN	mg/L	32	20.5	26.2	23.3	1.3
	AC	mg/L	32	20.9	26.3	23.4	1.2
	TA	mg/L	20	20.9	26.0	23.2	1.3
	TB	mg/L	20	20.7	25.6	23.3	1.3
	TT	mg/L	12	20.8	24.1	22.9	1.1
Turbidity	IN	NTU	32	0.6	15.0	5.6	4.2
	AC	NTU	32	0.4	4.0	0.9	0.7
	TA	NTU	20	<0.1	1.5	0.3	0.4
	TB	NTU	20	<0.1	2.2	0.4	0.5
	TT	NTU	12	<0.1	5.0	0.8	1.4
TOC	IN	mg/L	25	1.5	2.9	1.9	0.3
	AC	mg/L	25	1.5	2.8	1.9	0.3
	TA	mg/L	1	1.2	1.2	1.2	–
	TB	mg/L	1	1.2	1.2	1.2	–
	TT	mg/L	24	1.5	3.0	1.9	0.3
pH	IN	S.U.	29	6.9	7.6	7.2	0.2
	AC	S.U.	29	7.0	7.5	7.2	0.2
	TA	S.U.	8	7.1	7.4	7.3	0.1
	TB	S.U.	8	7.1	7.4	7.3	0.1

Table 4-9. Summary of Water Quality Parameter Sampling Results (Continued)

Parameter	Sample Location	Unit	Sample Count	Concentration			Standard Deviation
				Minimum	Maximum	Average	
pH (Continued)	TT	S.U.	22	7.0	7.5	7.2	0.2
Temperature	IN	°C	31	9.0	15.0	11.8	1.4
	AC	°C	31	10.0	15.7	12.1	1.4
	TA	°C	8	10.9	14.1	12.3	0.9
	TB	°C	8	11.0	14.2	12.3	0.9
	TT	°C	24	10.0	17.2	12.2	1.9
DO	IN	mg/L	30	0.0	4.7	0.8	0.9
	AC	mg/L	29	0.3	4.3	1.6	0.8
	TA	mg/L	8	1.2	2.1	1.6	0.3
	TB	mg/L	8	1.0	1.7	1.4	0.2
	TT	mg/L	22	0.8	3.7	1.6	0.7
ORP	IN ^(b)	mV	25	-93.3	-14.0	-49.1	16.5
	AC	mV	27	42.0	474	315	88.7
	TA	mV	8	71.0	440	341	127
	TB	mV	8	75.0	460	337	124
	TT	mV	20	205	435	332	71.4
Free Chlorine (as Cl ₂)	AC	mg/L	37	0.0	2.5	0.7	0.7
	TA	mg/L	8	0.0	2.1	0.7	0.8
	TB	mg/L	8	0.0	1.9	0.5	0.6
	TT	mg/L	31	0.1	1.8	0.8	0.5
Total Chlorine (as Cl ₂)	AC	mg/L	37	0.4	3.5	2.4	0.8
	TA	mg/L	8	0.6	3.3	2.5	0.9
	TB	mg/L	8	0.1	3.9	2.7	1.1
	TT	mg/L	31	0.7	3.3	2.3	0.7
Total Hardness (as CaCO ₃)	IN	mg/L	14	231	436	351	48.4
	AC	mg/L	14	230	452	354	52.7
	TA	mg/L	2	224	358	291	94.5
	TB	mg/L	2	225	360	292	95.9
	TT	mg/L	12	295	457	366	47.5
Ca Hardness (as CaCO ₃)	IN	mg/L	14	101	241	197	36.7
	AC	mg/L	14	100	251	198	38.9
	TA	mg/L	2	96.9	235	166	97.9
	TB	mg/L	2	95.7	237	166	99.8
	TT	mg/L	12	161	251	205	25.4
Mg Hardness (as CaCO ₃)	IN	mg/L	14	122	215	154	27.6
	AC	mg/L	14	124	236	156	30.2
	TA	mg/L	2	123	127	125	3.4
	TB	mg/L	2	123	129	126	3.9
	TT	mg/L	12	126	264	160	37.9

One-half of detection limit used for samples with concentrations less than detection limit for calculations.

- (a) 09/09/08 samples not analyzed by laboratory because sample cooler was out of required temperature range (i.e., >4°C).
- (b) Data at IN and AC on 11/18/09 and at TB on 05/20/09 not used in statistical analysis due to abnormal results.
- (c) Average and standard deviation calculations not meaningful due to phosphorus breakthrough from adsorption vessels; see breakthrough curves in Figure 4-15 for total phosphorus concentrations.
- (d) Data collected on 07/22/08, 11/18/08, and 12/03/08 not used in statistical analysis due to abnormal results.

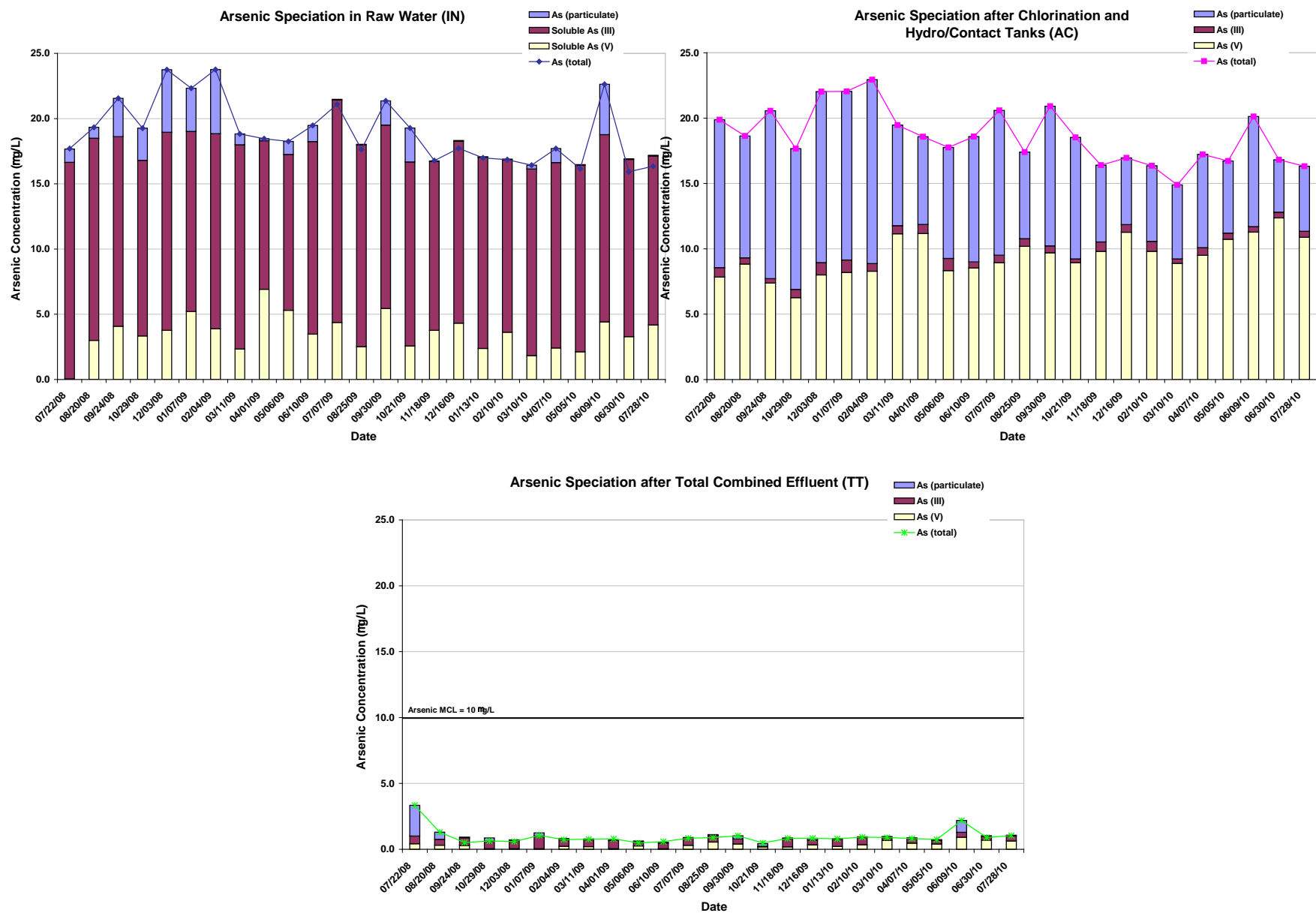


Figure 4-11. Concentrations of Arsenic Species at IN, AC, and TT Sampling Locations

Figure 4-12 plots total arsenic concentrations measured across the treatment train against throughput in BV. Throughout the performance evaluation study, total arsenic concentrations were reduced to levels well below 10 µg/L, with the highest concentration measured at 3.3 µg/L. Amounts of arsenic measured consisted of no more than 0.9 µg/L of soluble As(V), 1.0 µg/L of soluble As(III), and 2.3 µg/L of particulate arsenic. Both soluble As(V) and particulate arsenic were removed by AD-33 media, presumably via adsorption and filtration, respectively. Very little soluble As(III) was removed by the media; the average concentrations before and after adsorption were 0.6 and 0.5 µg/L, respectively.

As shown in Figure 4-12, total arsenic concentrations measured after the hydro/contact tanks were lower than those measured in raw water for most samples. This is consistent with the average concentrations (19.2 vs. 19.6 µg/L) shown in Table 4-8. As discussed earlier, the long residence time (11 hr) in the hydro/contact tanks had caused some particles to settle, reducing both arsenic and iron concentrations at the AC location. The concentration reduction for iron was much more significant than that for arsenic as discussed below under the subsection *Iron and Manganese*.

Based on the final sampling event conducted on July 28, 2010, the total arsenic concentration in the system effluent (TT) was 1.0 µg/L. Throughout the demonstration period, the system treated 33,158,300 gal (or 45,230 BV; 1 BV = 98 ft³ = 733 gal) of water. This volume throughput was about 70% of the vendor-estimated media life of 65,000 BV (47,645,000 gal). Therefore, it is undetermined at this time whether the AD-33 media would achieve the vendor-estimated media life.

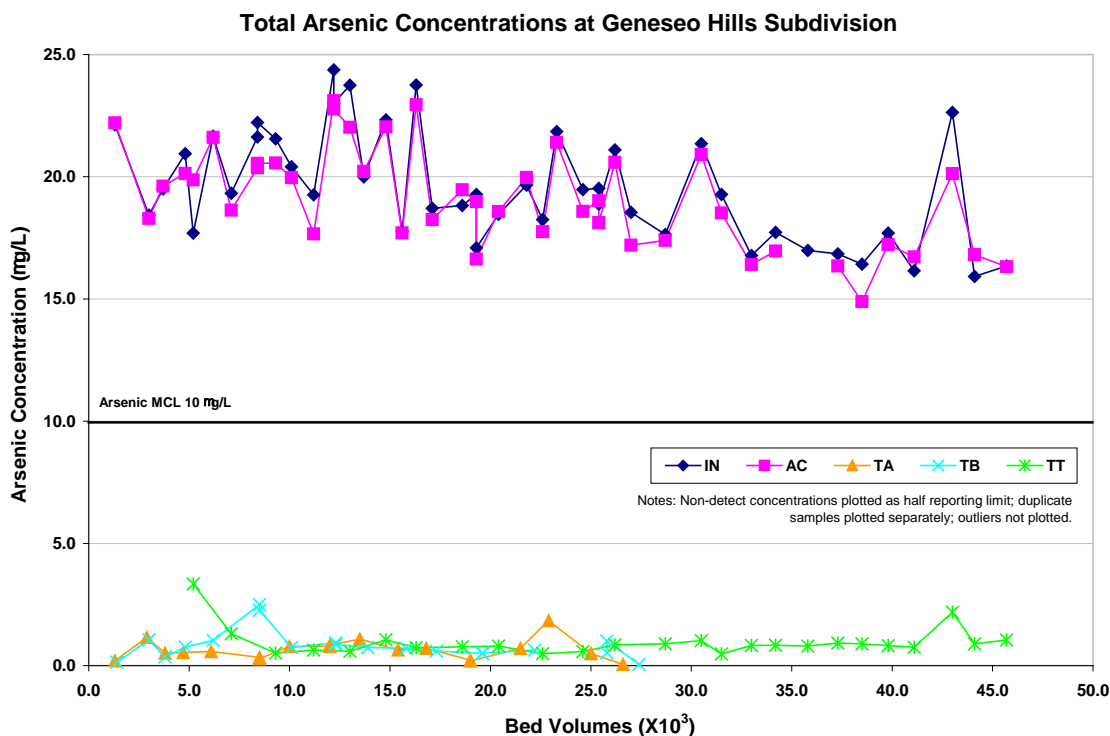


Figure 4-12. Total Arsenic Breakthrough Curves

Iron and Manganese. On eight occasions on December 3, 2008; January 7, March 11, and November 18, 2009; and January 13, February 10, April 7, and June 9, 2010; soluble iron and manganese concentrations in raw water were significantly greater than respective total iron and manganese

concentrations (see Appendix B). The higher soluble concentrations observed most likely were the results of data transcription errors because under no circumstance could a soluble concentration be higher than the corresponding total concentration. Therefore, the measurements in question were substituted for one another for statistical calculations and data plots (see Table 4-8 and Figures 4-13 and 4-14).

Total iron concentrations in raw water varied extensively, ranging from 84.6 to 1,329 $\mu\text{g/L}$ and averaging 554 $\mu\text{g/L}$ (see Figure 4-13). Approximately 65% of the total iron was present in the soluble form. It was not clear what had caused iron concentrations to vary. After chlorination and the hydro/contact tanks, concentrations of total iron, existing entirely as particulate iron, were much more consistent, ranging from 204 to 602 $\mu\text{g/L}$ and averaging 347 $\mu\text{g/L}$. This average concentration was 37% less than that in raw water, presumably caused by settling of iron particles in the hydro/contact tanks. The remaining amount (347 $\mu\text{g/L}$) was completely removed by AD-33 media from all but six samples with the highest concentration measured at 83.7 $\mu\text{g/L}$ (see Appendix B). Particulate iron removal most likely was achieved via filtration.

Although not as extensively, total manganese concentrations in raw water also varied, ranging from 4.4 to 19.9 $\mu\text{g/L}$ and averaging 8.0 $\mu\text{g/L}$ (Figure 4-14). Manganese existed almost entirely in the soluble form. Total manganese concentrations after chlorination and the hydro/contact tanks were reduced to an average of 6.3 $\mu\text{g/L}$. Chlorination, however, did not precipitate manganese as it did for iron. Slow oxidation kinetics most likely was the reason (McCall et al., 2007; Condit and Chen, 2006; Knocke et al., 1990; Knocke et al., 1987). Soluble manganese remained untreated after the AD-33 adsorption vessels.

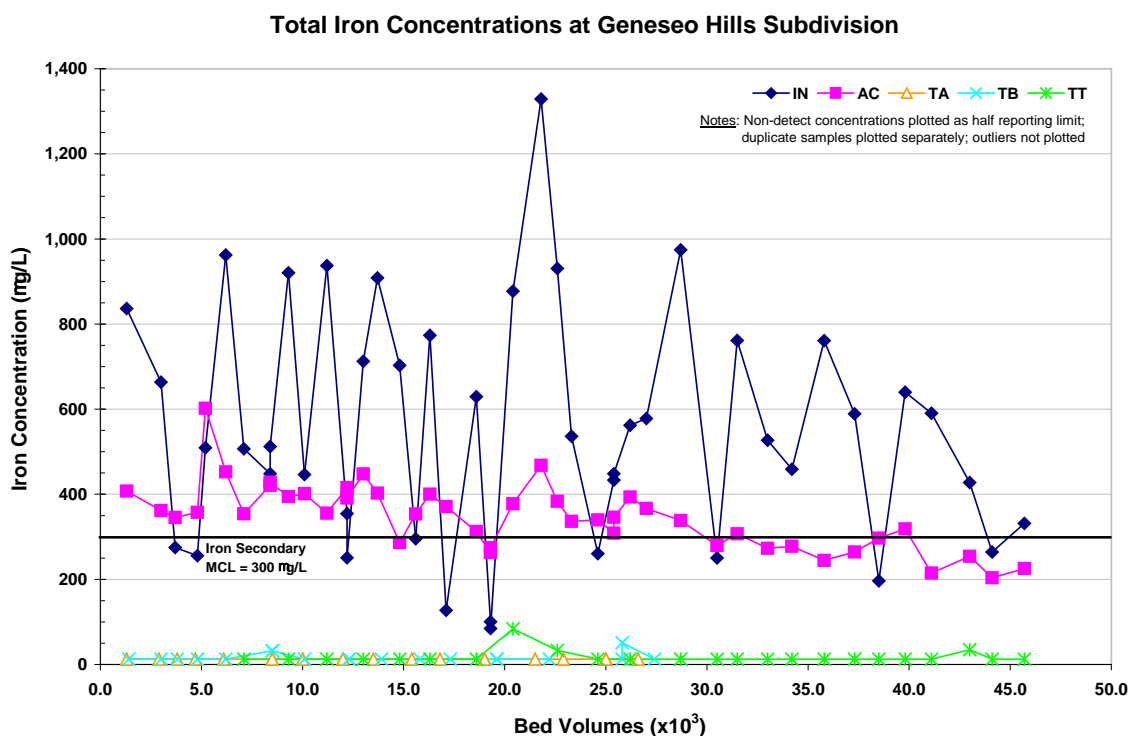
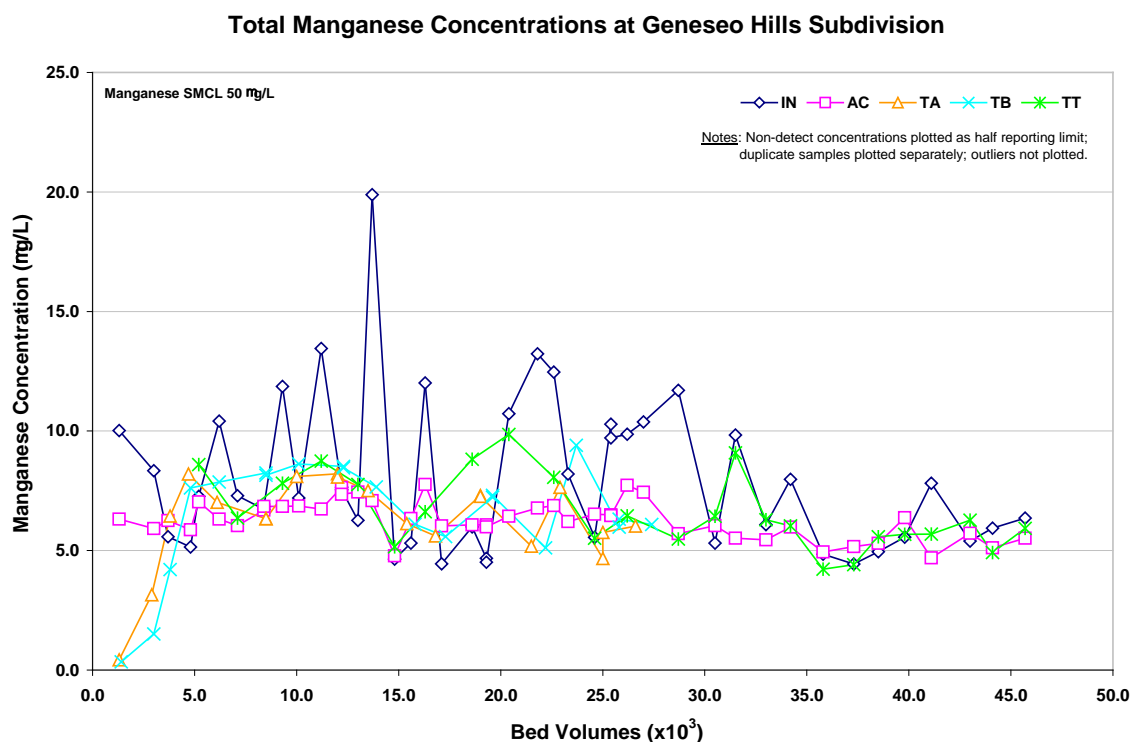


Figure 4-13. Total Iron Breakthrough Curves

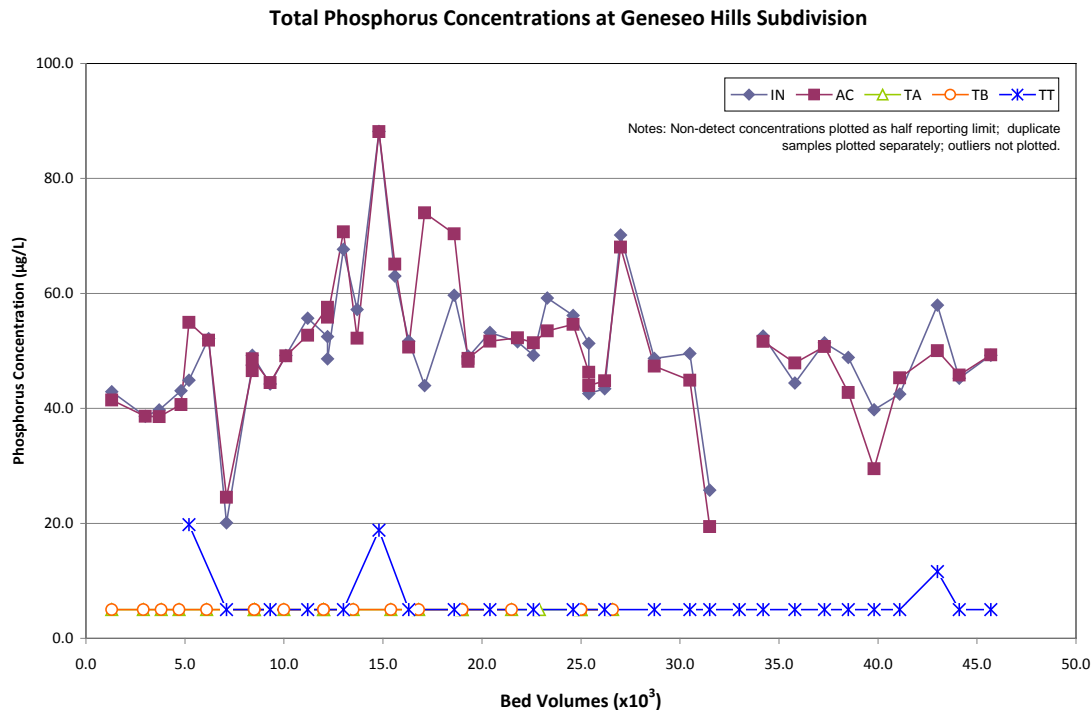


Competing Anions. Total phosphorous concentrations in raw water ranged from 20.1 to 88.2 $\mu\text{g/L}$ and averaged 49.8 $\mu\text{g/L}$, which remained essentially unchanged after chlorination and the hydro/contact tanks. After the adsorption vessels, total phosphorous concentrations were reduced to its MDL of 10 $\mu\text{g/L}$ for all but three samples (at 11.6, 18.8, and 19.8 $\mu\text{g/L}$; see Appendix B). Therefore, phosphorus competes with arsenic for available adsorption sites, thus adversely affecting system performance. Similar observations were made at other arsenic demonstration sites (McCall et al., 2009). Figure 4-15 shows total phosphorous concentrations across the treatment train as a function of throughput.

In contrast, silica concentrations remained relatively constant across the treatment train, averaging from 22.9 mg/L (as SiO_2) at TT to 23.4 mg/L (as SiO_2) at AC (see Table 4-9). As much as 0.5 mg/L of silica, however, could have been removed by AD-33 media, thus affecting arsenic adsorption. Adsorption of silica by various AM at other arsenic demonstration sites has been reviewed elsewhere (Chen et al., 2011).

Other Water Quality Parameters. As shown in Table 4-9, pH values in raw water (IN) ranged from 6.9 to 7.6 and averaged 7.2. After chlorination and the two hydro/contact tanks (AC), pH values remained essentially unchanged, ranging from 7.0 to 7.5 and averaging 7.2. These pH values are well within the recommended pH range of 6.0 to 8.0 for optimal arsenic adsorption. After treatment, average pH values remained constant, ranging from 7.2 to 7.3 at the TA, TB, and TT locations.

Alkalinity levels in raw water and treated water averaged 380 and 379 mg/L (as CaCO_3), respectively. Total hardness levels in raw water and treated water ranged from 231 to 436 mg/L (as CaCO_3) and 224 to 457 mg/L (as CaCO_3), respectively. Turbidity levels in raw water and treated water averaged 5.6 and 0.5 NTU, respectively. Average fluoride concentrations ranged from 0.3 to 0.6 mg/L at all sampling



locations, well below the fluoride MCL of 4 mg/L. Average sulfate concentrations ranged from <0.1 to 0.3 mg/L at all sampling locations. All nitrate concentrations were below the MDL of 0.05 mg/L (as N) at all sampling locations. TOC levels averaged 1.9 mg/L at all sampling locations. In general, the results indicated that AD-33 media did not affect alkalinity, total hardness, turbidity, fluoride, sulfate, nitrate, and TOC levels in the treated water.

4.5.2 Backwash Wastewater and Residual Solids Sampling. Table 4-10 presents analytical results of 12 monthly backwash wastewater sampling events conducted from November 18, 2008, through October 21, 2009. In general, backwash wastewater concentrations were consistent between sampling events and between Vessels A and B. pH values ranged from 7.2 to 7.8 and averaged 7.4. TDS concentrations ranged from 306 to 406 mg/L and averaged 352 mg/L. TSS concentrations ranged from 125 to 590 mg/L and averaged 252 mg/L. As expected, arsenic, iron, and manganese existed primarily in the particulate form, with concentrations averaging 1,100 µg/L for particulate arsenic, 68,249 µg/L for particulate iron, and 252 µg/L for particulate manganese. Although much lower than total iron levels, soluble iron levels were uncharacteristically high, averaging 359 and 844 µg/L for Vessels A and B, respectively. It was not clear why soluble iron concentrations were so high. Two possible explanations were penetration of fine iron particles through the 0.45 µm disc filters used for sample filtration and accidental spill/drips of some unfiltered water into filtered sample bottles. However, there has been no evidence to suggest that either of these in fact had occurred during onsite sampling.

Assuming 252 mg/L of TSS in 3,915 gal of wastewater, 8.2 lb of solids would be generated during each backwash event. Based on the average particulate metal concentrations mentioned above, the solids would consist of approximately 0.04 lb of arsenic, 2.2 lb of iron, and 0.02 lb of manganese. These amounts represent 0.44%, 27.1%, and 0.21% of the total solids produced.

Table 4-10. Backwash Wastewater Sampling Results

Sampling Event		BW1										BW2									
		Vessel A										Vessel B									
		pH	TDS	TSS	As (total)	As (soluble)	As (particulate)	Fe (total)	Fe (soluble)	Mn (total)	Mn (soluble)	pH	TDS	TSS	As (total)	As (soluble)	As (particulate)	Fe (total)	Fe (soluble)	Mn (total)	Mn (soluble)
No.	Date	S.U.	mg/L	mg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	S.U.	mg/L	mg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L
1	11/18/08	7.6	352	190	732	14.6	718	63,425	731	75	8.1	7.4	322	305	1,360	16.0	1,344	103,740	791	140	7.7
2	12/17/08	7.7	370	235	957	8.3	948	80,013	356	129	8.6	7.5	366	260	1,109	13.3	1,096	81,146	745	126	7.8
3	01/21/09	7.4	354	230	869	9.7	859	62,049	387	86.4	6.2	7.4	350	290	897	10.8	886	66,847	452	93.2	6.3
4	02/18/09	7.2	362	206	723	9.3	714	47,641	434	82.9	6.7	7.2	306	206	723	11.3	712	47,731	456	82.8	6.6
5	03/18/09	7.3	314	244	1,080	8.6	1,071	60,122	331	117	9.7	7.3	334	225	1,084	14.5	1,069	62,624	544	120	10.0
6	04/22/09	7.8	306	370	1,219	15.5	1,203	71,830	299	126	4.6	7.4	360	590	3,599	44.1	3,554	164,675	3,793	416	23.5
7	05/20/09	7.4	406	238	781	5.9	776	45,563	140	122	8.7	7.3	380	234	793	7.0	786	43,354	215	118	7.7
8	06/24/09	7.4	358	300	1,369	5.4	1,364	86,712	214	22.4	7.4	7.5	352	275	1,225	4.0	1,221	85,195	242	21.5	8.3
9	07/22/09	7.3	368	200	1,185	1.3	1,183	51,488	161	2,962	6.7	7.4	350	210	1,002	3.3	999	59,143	276	196	6.2
10	08/25/09	7.2	372	250	1,326	17.4	1,309	84,566	782	218	7.6	7.2	354	230	1,287	40.8	1,246	84,619	1,926	213	10.5
11	09/30/09	7.3	360	240	1,180	7.5	1,173	66,299	245	158	7.3	7.3	356	210	1,121	8.0	1,113	66,840	321	158	6.5
12	10/21/09	7.4	346	125	554	8.7	546	34,313	225	228	14.6	7.3	342	180	529	10.5	518	32,468	364	244	13.6
Minimum		7.2	306	125	554	1.3	546	34,313	140	22.4	4.6	7.2	306	180	529	3.3	518	32,468	215	21.5	6.2
Maximum		7.8	406	370	1,369	17.4	1,364	86,712	782	2,962	14.6	7.5	380	590	3,599	44.1	3,554	164,675	3,793	416	23.5
Average		7.4	356	236	998	9.3	989	62,835	359	360	8.0	7.4	348	268	1,227	15.3	1,212	74,865	844	161	9.5

TDS = total dissolved solids; TSS = total suspended solids

Solids in wastewater were collected during two backwash events on November 18, 2008, and April 22, 2009, as discussed in Section 3.3.3. Table 4-11 presents analytical results of the solids sampled. On a dry weight basis, arsenic, iron, and manganese constituted 0.3%, 27.4%, and 0.05%, respectively, of the total solids produced, which are rather close to the results (i.e., 0.44%, 27.1%, and 0.21%) calculated based on TSS and metal concentrations analyzed in wastewater.

A solid sample also was collected from the sludge holding tank on June 24, 2010; results also are presented in Table 4-11. In general, the sludge had higher metal contents than the backwash solids collected on November 18, 2008, and April 22, 2009, with some (such as Mg, P, Ca, Fe, As, and Ba) 19 to 70% higher and others (such as Si and Mn) 116 to 418% higher.

Table 4-11. Backwash Residual Solid Sampling Results

Date	Location	Mg	Si	P	Ca	Fe	Mn	As	Ba
		µg/g	µg/g	µg/g	µg/g	µg/g	µg/g	µg/g	µg/g
11/18/08	Vessel A	6,324	1,672	6,853	31,325	188,353	308	1,549	770
	Vessel B	6,109	1,546	7,456	30,434	194,413	313	1,733	742
	Average	6,217	1,609	7,155	30,880	191,383	311	1,641	756
04/22/09	Vessel A	15,387	5,105	19,274	82,408	345,466	603	4,411	1,925
	Vessel B	12,983	5,299	18,051	66,533	369,713	699	4,293	1,732
	Average	14,185	5,202	18,663	74,471	357,590	606	4,352	1,829
Average		10,201	3,406	12,909	52,676	274,487	459	2,997	1,293
06/24/10	Sludge Tank	12,117	17,663	19,482	65,063	424,735	991	5,108	1,853

4.5.3 Spent Media. As stated in Section 3.3.4., AD-33 media in Vessels A and B was not replaced because arsenic breakthrough at 10 µg/L was not reached during the demonstration study; therefore, no spent media was produced as residual solids.

4.5.4 Distribution System Water Sampling. Prior to installation and operation of the treatment system, baseline distribution system water samples were collected at two residences and at Storage Tank #2 on March 10, March 17, March 24, and March 31, 2008. Following installation and startup of the treatment system, distribution water sampling continued on a monthly basis at the same three locations, with samples collected on 12 occasions from August 6, 2008, through July 22, 2009. As discussed in Section 3.3.5., Storage Tank #2 was sampled by the operator as part of distribution system water sampling, but it is not part of the LCR and serves as a large water main; therefore, there is no stagnation time. Table 4-12 presents results of distribution system water sampling.

The most significant change in the distribution system water quality since the treatment system began operation was a decrease in arsenic concentrations. Baseline arsenic concentrations ranged from 8.6 to 34.1 µg/L and averaged 18.1 µg/L for all three locations. After system startup, arsenic concentrations decreased at all three locations, ranging from 1.8 to 11.2 µg/L and averaging 4.4 µg/L. On September 9 and October 8, 2008, arsenic concentrations exceeded the MCL of 10 µg/L at Residence #2 (at 11.2 µg/L) and Storage Tank #2 (at 10.4 µg/L), respectively. However, the remaining samples contained lower arsenic concentrations, ranging from 1.8 to 8.5 µg/L for all three locations. Arsenic concentrations in distribution water were somewhat higher than those in system effluent, suggesting redissolution and/or resuspension of arsenic in the distribution system (Lytle, 2005).

Table 4-12. Distribution System Sampling Results

No. of Sampling Events		DS1									DS2									DS3										
	Address	Storage Tank #2									Residence #1									Residence #2										
	Sample Type	non-LCR									LCR									LCR										
	Flushed/ 1st Draw	Flushed									1st Draw									1st Draw										
	Sampling Date	Total Cl₂	Free Cl₂	pH	Alkalinity	As	Fe	Mn	Pb	Cu	Stagnation Time	Total Cl₂	Free Cl₂	pH	Alkalinity	As	Fe	Mn	Pb	Cu	Stagnation Time	Total Cl₂	Free Cl₂	pH	Alkalinity	As	Fe	Mn	Pb	Cu
No.	Date	mg/L	mg/L	S.U.	mg/L	µg/L	µg/L	µg/L	µg/L	µg/L	hrs	mg/L	mg/L	S.U.	mg/L	µg/L	µg/L	µg/L	µg/L	µg/L	hrs	mg/L	mg/L	S.U.	mg/L	µg/L	µg/L	µg/L	µg/L	µg/L
BL1	03/10/08 ^(a)	1.2	0.6	7.2	375	9.3	29	5.1	28.8	143	6.0	0.0	0.2	8.2	379	10.5	43	5.4	0.1	939	6.0	1.1	0.5	7.4	381	10.6	26	4.2	0.4	403
BL2	03/17/08 ^(a)	1.5	0.4	7.2	378	9.0	43	6.2	13.4	245	6.0	0.1	0.0	7.2	390	28.6	489	6.9	3.8	1,083	6.0	0.1	0.2	7.2	384	27.9	243	6.9	2.5	496
BL3	03/24/08	2.7	0.7	7.2	375	8.6	45	5.6	3.4	80.1	6.0	0.0	0.0	7.2	379	34.1	760	7.6	7.1	1,586	6.0	2.8	0.8	7.2	371	26.2	445	7.8	2.0	884
BL4	03/31/08	3.0	1.2	7.6	378	10.3	217	6.8	9.7	150	6.0	3.0	1.0	7.3	376	22.9	483	7.0	4.3	1,520	6.0	3.1	1.3	7.3	376	19.0	443	6.6	3.2	657
1	08/06/08	NA	NA	7.5	378	4.7	76	7.6	11.7	54.3	6.8	NA	NA	7.2	386	4.8	85	8.3	0.9	771	6.8	NA	NA	7.3	380	4.2	35	5.1	0.7	108
2	09/09/08	NA	NA	7.4	NA ^(b)	3.1	34	6.7	4.0	25.8	6.0	NA	NA	7.3	NA ^(b)	4.0	36	7.3	0.2	1,107	6.0	NA	NA	7.7	NA ^(b)	11.2	292	7.7	0.9	835
3	10/08/08	NA	NA	7.6	368	10.4	26	7.6	1.6	4.8	6.0	NA	NA	7.3	372	4.6	68	8.3	1.2	875	6.1	NA	NA	7.3	377	5.9	76	8.6	1.2	953
4	11/18/08	NA	NA	7.2	371	3.7	65	8.3	22.9	54.5	6.0	NA	NA	7.5	369	3.5	26	8.1	1.2	894	6.0	NA	NA	7.3	364	5.7	71	7.6	0.8	578
5	12/17/08	NA	NA	7.3	372	2.4	43	7.2	2.9	60.4	6.0	NA	NA	7.3	372	4.7	94	7.2	3.2	764	6.0	NA	NA	7.3	370	4.1	236	6.8	0.9	548
6	01/21/09	NA	NA	7.9	361	2.1	<25	6.4	3.2	72.7	6.1	NA	NA	7.4	372	3.6	38	4.9	2.3	604	6.1	NA	NA	7.4	367	4.0	32	6.1	0.7	281
7	02/18/09	NA	NA	7.0	384	2.0	34	4.8	3.4	112	6.0	NA	NA	7.1	387	3.2	43	4.6	1.4	796	6.0	NA	NA	7.2	382	4.4	83	4.9	1.1	465
8	03/18/09	NA	NA	7.3	390	1.8	<25	6.3	4.8	118	6.0	NA	NA	8.2	388	3.1	<25	6.4	1.1	350	6.0	NA	NA	7.4	395	2.9	<25	7.5	0.5	412
9	04/22/09	NA	NA	7.9	382	4.1	64	5.9	4.6	168	6.0	NA	NA	7.4	392	5.2	156	4.9	4.4	970	6.0	NA	NA	8.1	394	8.5	308	10.7	5.4	544
10	05/20/09	NA	NA	7.2	404	4.8	<25	6.8	3.3	24.1	6.0	NA	NA	7.6	404	3.3	48	6.8	1.6	1,192	6.0	NA	NA	7.3	396	2.2	<25	7.3	0.4	422
11	06/24/09	NA	NA	7.2	382	8.5	37	7.5	2.2	13.6	6.0	NA	NA	7.3	386	2.5	<25	3.8	0.7	856	6.0	NA	NA	7.8	382	2.8	<25	3.9	0.3	468
12	07/22/09	NA	NA	7.3	370	7.2	<25	8.3	0.2	7.8	6.0	NA	NA	7.3	379	2.5	<25	3.7	0.3	820	6.0	NA	NA	7.3	372	2.5	<25	3.4	0.2	474
Average Before System Start-up		—	—	7.3	377	9.3	83	5.9	13.8	154	—	—	—	7.5	381	24.0	444	6.7	3.8	1,282	—	—	—	7.3	378	20.9	289	6.4	2.0	610
Average After System Start-up		—	—	7.4	378	4.6	47	6.9	5.4	59.7	—	—	—	7.4	382	3.7	66	6.2	1.5	833	—	—	—	7.5	380	4.9	142	6.6	1.1	507
Average Before System Start-up for All Three Locations																							7.3	379	18.1	272	6.3	6.6	682	
Average After System Start-up for All Three Locations																							7.4	380	4.4	85	6.6	2.7	467	

Lead action level = 15 µg/L; copper action level = 1,300 µg/L

The unit for alkalinity is mg/L as CaCO₃.

(a) Chlorine measurements taken at Battelle on 04/17/08.

(b) Samples out of temperature for alkalinity.

BL = baseline sampling; NA = not available

Similarly to arsenic concentrations, iron concentrations decreased in distribution water since the system began operation. Iron concentrations at Residence #1, Residence #2, and Storage Tank #2 averaged 444, 289, and 83 µg/L, respectively, before system startup; their concentrations decreased to 66, 142, and 47 µg/L (on average), respectively, after system startup. These concentrations, although low, were still higher than those (<25 µg/L) measured in the system effluent. Therefore, some iron also could have been reintroduced to water in the distribution system. Manganese concentrations were low both before and after system startup at 6.3 and 6.6 µg/L (on average), respectively.

Before system startup, lead concentrations at Residences #1 and #2 ranged from 0.1 to 7.1 µg/L and averaged 2.9 µg/L. After startup, lead concentrations at these two locations reduced slightly, ranging from 0.2 to 5.4 µg/L and averaging 1.3 µg/L. No sample exceeded the action level of 15 µg/L. At Storage Tank #2, lead concentrations were more irregular, ranging from 3.4 to 28.8 µg/L before system startup and from 0.2 to 22.9 µg/L after system startup. The lead action level was exceeded once before system startup on March 10, 2008, at 28.8 µg/L and once after system startup on November 18, 2008, at 22.9 µg/L. Average copper concentrations varied significantly at each location, ranging from 154 to 1,282 µg/L before system startup and from 59.7 to 833 µg/L after system startup. The only samples that exceeded the action level of 1,300 µg/L were collected at Residence #1 before system startup on March 24, at 1,586 µg/L and March 31, 2008, at 1,520 µg/L.

pH values before system startup averaged 7.3 for all three locations, which remained essentially unchanged after system startup. Alkalinity also remained unchanged before and after system startup for all three locations. Average alkalinity concentrations before and after system startup were 379 and 380 mg/L (as CaCO₃), respectively.

4.5.5 Fire Hydrant Flush Solid Sampling. As described in Section 3.3.6, fire hydrant flush samples were collected by the operator from four fire hydrants located within the Subdivision on April 21, 2010. Although fire hydrant flush samples were collected from four locations, only the fire hydrants located at Deer Path Court and Prairie Dawn Drive produced enough solids for analysis. The analytical results from the fire hydrant flush solid samples are presented in Table 4-13. Metals concentrations of the fire hydrant flush solids are within the range of those of the backwash solids.

Table 4-13. Fire Hydrant Flush Solid Sample Results

Fire Hydrant Location	Mg	Si	P	Ca	Fe	Mn	As	Ba
	µg/g	µg/g	µg/g	µg/g	µg/g	µg/g	µg/g	µg/g
Deer Path Ct.	21,334	8,156	13,014	58,948	198,716	328	3,316	1,105
Prairie Dawn Dr.	41,082	20,638	8,226	138,675	215,692	143	1,808	943

4.6 System Cost

System cost is evaluated based on the capital cost per gpm (or gpd) of the design capacity and the O&M cost per 1,000 gal of water treated. The capital cost includes the cost for equipment, site engineering, and installation. The O&M cost includes the cost for media replacement and disposal, electrical power consumption, and labor.

4.6.1 Capital Cost. The total capital investment for equipment, site engineering, and installation of the treatment system was \$139,149 (see Table 4-14). The equipment cost was \$101,290 (or 73% of the total capital investment), which included \$28,940 for two media vessels, \$26,500 for AD-33 media and

Table 4-14. Capital Investment Cost for APU Arsenic Adsorption System

Description	Quantity	Cost	% of Capital Investment
<i>Equipment Cost</i>			
Media Vessels	2	\$28,940	—
E33 Media	100 ft ³	\$26,000	—
Gravel Underbedding	20 ft ³	\$500	—
Process Valves & Piping	—	\$27,590	—
Instrumentation & Controls	—	\$12,620	—
Additional Sample Taps	2	\$210	—
O&M Manuals	3	\$900	—
One-Year O&M Support	—	\$1,790	—
Shipping	—	\$2,740	—
Equipment Total	—	\$101,290	73%
<i>Engineering Cost</i>			
Vendor Labor	—	\$7,895	—
Subcontractor Labor	—	\$11,650	—
Engineering Total	—	\$19,545	14%
<i>Installation Cost</i>			
Vendor Labor for System Startup	—	\$2,730	—
Vendor Travel for System Startup	—	\$985	—
Subcontractor Material	—	\$7,669	—
Subcontractor Electrical Material/Labor	—	\$1,780	—
Subcontractor Labor	—	\$5,150	—
Installation Total	—	\$18,314	13%
Total Capital Investment	—	\$139,149	100%

gravel underbedding (\$260 and \$25/ft³, respectively), \$27,590 for process valves and piping, \$12,620 for instrumentation and controls, \$210 for additional sample taps, and \$2,740 for shipping. The costs for O&M manuals and one-year of O&M support were \$900 and \$1,790, respectively.

The site engineering cost included the cost for the preparation of system/site engineering plans and drawings for piping tie-ins, electrical requirements for system components, and system layout and footprint to facilitate building modifications, as well as submission of a permit application package to IL EPA for approval. The site engineering cost was \$19,545 (or 14% of the total capital investment). Site engineering was performed by AdEdge and Missman, Stanley & Associates, an engineering subcontractor for AdEdge.

The installation cost included the equipment and labor to unload and install the skid-mounted unit, perform piping tie-ins and electrical work, load and backwash the media, and perform system shakedown and startup. The installation cost was \$18,314 (or 13% of the total capital investment).

The total capital cost of \$139,149 was normalized to the system's rated capacity of 200 gpm (or 288,000 gpd), which results in \$696/gpm (or \$0.48 gpd) of design capacity. The capital cost also was converted to an annualized cost of \$13,134/yr using a capital recovery factor (CRF) of 0.09439 based on a 7% interest rate and a 20-year return period. Assuming that the system operated 24 hr/day, 7 day/week at the design flowrate of 200 gpm to produce 105,120,000 gal/year, the unit capital cost would be \$0.12/1,000 gal.

During the demonstration period from May 8, 2008 through July 30, 2010, the system produced 33,158,000 gal of water (see Table 4-6) or 14,868,000 gal/year on average. At this reduced rate of usage, the unit capital cost increased to \$0.88/1,000 gal.

4.6.2 Operation and Maintenance Cost. The O&M cost included the cost for items such as media replacement and disposal, electricity consumption, and labor (see Table 4-15). Although media replacement did not occur during the system performance evaluation, the media replacement cost would have represented the majority of the O&M cost at an estimated \$31,215 to change out the media in both vessels. The media change-out cost would include the cost for the new media, gravel underbedding, freight, labor, travel, spent media analysis, and the media disposal fee. This cost was used to estimate the media replacement cost per 1,000 gal of water treated as a function of the projected media run length to the 10 µg/L arsenic breakthrough (Figure 4-16).

Chlorination using NaOCl for disinfection purposes and fluoridation using H₂SiF₆ existed prior to the installation and operation of the treatment system. Because system operation did not affect the use rate of either NaOCl or H₂SiF₆, the incremental chemical cost for each was negligible. Electrical power consumption was calculated based on the difference between the average monthly cost from electric bills before and after system startup. The difference in electrical consumption (kWh) before and after system startup was negligible. Under normal operating conditions, routine labor activities to operate and maintain the system consumed 0.35 hr/day, 3 visits/week, or 1.0 hr/week (on average). The labor cost for routine labor activities during the study period was \$1,725 or \$0.05/1,000 gal of water treated (see Table 4-15).

Table 4-15. Operation and Maintenance Cost for APU Arsenic Adsorption System

Cost Category	Value	Assumptions
Volume Processed (gal)	33,158,000	During 815-day study period; equivalent to 14,868,000 gal/year (on average)
Media Replacement and Disposal Cost		
Media Replacement for 2 Vessels	\$26,000	\$260/ft ³ for 100 ft ³
Labor, Travel, Freight, & Disposal	\$5,215	
Media Replacement and Disposal (\$/1,000 gal)	See Figure 4-16	Based upon media run length at 10-μg/L arsenic breakthrough
Electricity Cost		
Electricity Cost (\$/month)	Negligible	
Electricity Cost (\$/1,000 gal)		
Labor Cost		
Average Weekly Labor (hr)	1.0	0.35 hr/visit, 3 visits/week on average
Total Labor (hr)	115	05/08/08–07/30/10
Total Labor Cost	\$1,725	Labor Rate = \$15.00/hr
Labor Cost (\$/1,000 gal)	0.05	
Total O&M Cost (\$/1,000 gal)	See Figure 4-16	Media replacement + \$0.05 (labor cost)

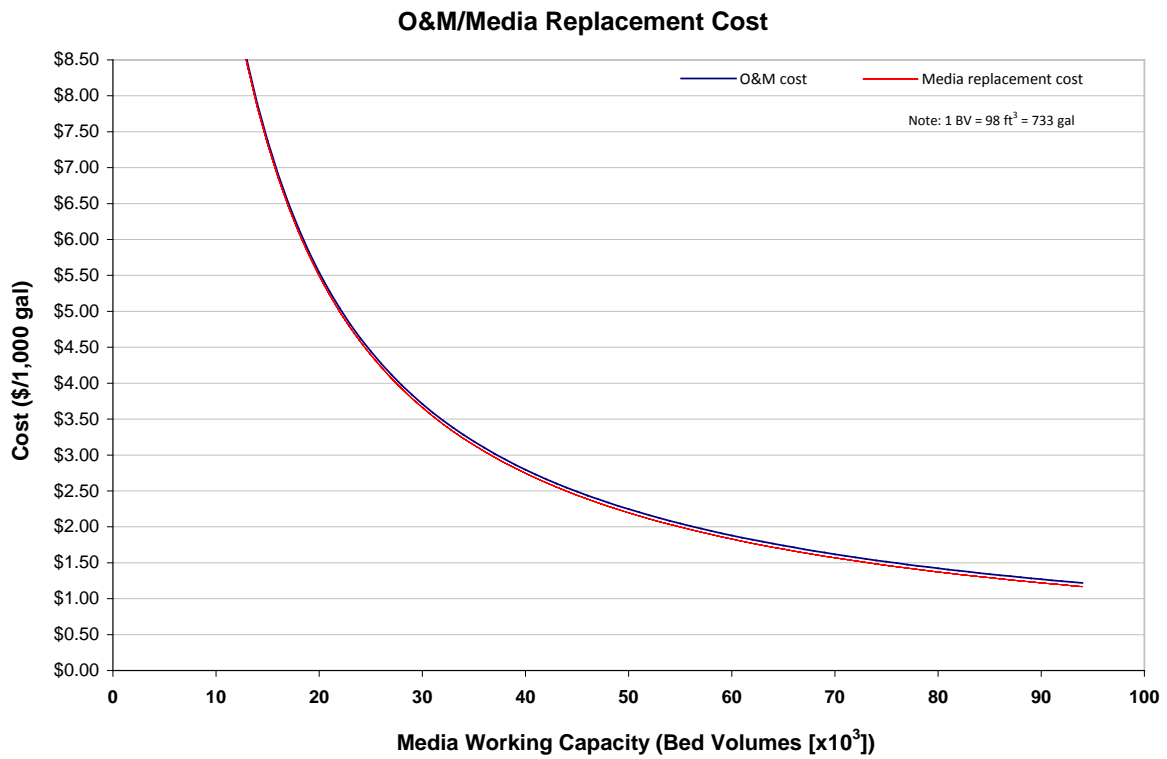


Figure 4-16. Media Replacement and Other Operation and Maintenance Cost

Section 5.0 REFERENCES

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APPENDIX A

OPERATIONAL DATA

Table A-1. EPA Arsenic Demonstration Project at Geneseo Hills Subdivision in Geneseo, IL - Daily System Operation Log Sheet

Week No.	Date	Time	Supply Well (No.5)			Vessel A		Vessel B		System			Vessel Back-wash
			Adjusted Pump Hours ^(a)	Adjusted Totalizer Meter	Avg Flowrate to Tanks	Instant Flowrate A	Cum. Flow Totalizer A	Instant Flowrate B	Cum. Flow Totalizer B	Cum. Bed Volume (A + B)	Inlet Pressure	Outlet Pressure	
			hr	gal	gpm	gpm	gal	gpm	gal	BV	psi	psi	
1	04/22/08	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	04/25/08	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
2	04/28/08	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	05/02/08	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
3	05/05/08	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	05/08/08	15:30	NA	0	NA	8	55,162	8	58,392	155	54	52	NA
4	05/09/08	11:30	NA	30,260	NA	14	71,660	15	75,785	201	54	52	NA
	05/12/08	12:00	NA	132,260	NA	11	128,545	11	136,441	361	59	58	NO
	05/14/08	17:30	NA	211,240	NA	17	173,885	17	185,362	490	54	52	NO
	05/16/08	14:00	NA	280,560	NA	24	213,566	25	226,113	600	52	49	A/B
5	05/19/08	14:00	NA	398,540	NA	11	282,284	11	295,336	788	53	51	NO
	05/21/08	13:00	NA	503,960	NA	8	343,386	7	360,445	960	54	52	NO
	05/23/08	11:45	NA	584,820	NA	25	388,926	25	402,432	1,080	54	52	A/B
6	05/28/08	12:00	NA	759,670	NA	11	405,197	11	419,917	1,126	60	58	NO
	05/30/08	12:40	NA	827,460	NA	9	443,033	10	460,736	1,233	54	52	NO
7	06/02/08	14:00	NA	957,280	NA	30	515,172	27	539,477	1,439	60	58	NO
	06/04/08	12:00	NA	1,023,280	NA	10	551,187	12	579,297	1,542	55	53	NO
	06/06/08	13:30	NA	1,094,660	NA	15	591,829	15	622,937	1,657	55	53	NO
8	06/09/08	10:00	NA	1,202,370	NA	17	653,346	18	686,714	1,828	60	58	NO
	06/11/08	10:30	NA	1,274,380	NA	16	696,004	16	731,347	1,947	56	54	NO
	06/13/08	12:30	NA	1,345,710	NA	19	737,426	20	774,412	2,062	50	48	NO
9	06/16/08	10:00	NA	1,459,680	NA	15	805,801	15	842,848	2,249	50	48	NO
	06/18/08	18:00	NA	1,534,570	NA	32	847,316	33	887,745	2,367	50	48	NO
	06/19/08	10:00	NA	1,570,100	NA	21	868,281	22	909,408	2,425	52	50	NO
	06/20/08	13:00	NA	1,617,970	NA	9	898,868	9	937,847	2,506	50	48	NO
10	06/23/08	11:00	NA	1,741,840	NA	19	968,060	19	1,009,981	2,698	54	52	NO
	06/25/08	13:00	NA	1,822,810	NA	21	1,015,801	20	1,057,087	2,828	54	52	NO
	06/27/08	12:00	NA	1,897,750	NA	26	1,062,606	25	1,098,841	2,949	56	54	NO
11	06/30/08	11:20	NA	2,011,130	NA	25	1,135,186	22	1,159,457	3,130	50	46	NO
	07/02/08	13:30	NA	2,094,610	NA	18	1,189,387	15	1,205,147	3,267	50	46	NO
	07/04/08	10:30	NA	2,167,350	NA	47	1,235,692	45	1,244,977	3,384	52	50	NO
12	07/07/08	14:00	NA	2,334,780	NA	15	1,337,046	17	1,339,287	3,651	58	56	NO
	07/09/08	13:30	NA	2,429,230	NA	22	1,395,736	21	1,393,972	3,806	52	50	NO
	07/11/08	15:20	NA	2,552,640	NA	7	1,458,526	0	1,454,957	3,975	50	48	NO
13	07/14/08	14:00	NA	2,657,380	NA	17	1,519,276	20	1,540,702	4,174	54	52	NO
	07/16/08	12:00	NA	2,745,380	NA	15	1,573,966	17	1,589,612	4,316	50	48	NO
	07/18/08	13:15	NA	2,834,630	NA	24	1,621,986	27	1,647,567	4,460	50	48	NO
14	07/22/08	10:00	NA	2,966,520	NA	21	1,682,413	22	1,712,166	4,631	53	50	A
	07/23/08	12:00	NA	3,017,610	NA	26	1,710,806	28	1,743,706	4,713	56	54	NO
	07/25/08	11:10	NA	3,078,490	NA	38	1,747,406	40	1,778,662	4,810	52	50	NO
15	07/28/08	13:20	NA	3,191,520	NA	19	1,815,106	18	1,845,220	4,993	46	44	NO
	07/30/08	13:00	NA	3,191,560	NA	20	1,861,147	19	1,890,137	5,117	52	50	NO
	08/01/08	12:15	NA	3,348,930	NA	13	1,910,239	12	1,937,763	5,249	46	44	NO
16	08/04/08	13:00	NA	3,481,220	NA	15	1,990,254	14	2,013,819	5,462	52	50	NO
	08/06/08	13:50	NA	3,539,280	NA	9	2,042,396	9	2,057,491	5,593	52	50	NO

**Table A-1. EPA Arsenic Demonstration Project at Geneseo Hills Subdivision in Geneseo, IL - Daily System Operation Log Sheet
(Continued)**

Week No.	Date	Time	Supply Well (No.5)			Vessel A		Vessel B		System			Vessel Back-wash
			Adjusted Pump Hours ^(a)	Adjusted Totalizer Meter	Avg Flowrate to Tanks	Instant Flowrate A	Cum. Flow Totalizer A	Instant Flowrate B	Cum. Flow Totalizer B	Cum. Bed Volume (A + B)	Inlet Pressure	Outlet Pressure	
			hr	gal	gpm	gpm	gal	gpm	gal	BV	psi	psi	
17	08/08/08	15:00	NA	3,628,330	NA	29	2,076,352	30	2,100,517	5,698	60	58	NO
	08/11/08	12:00	NA	3,747,730	NA	18	2,147,757	18	2,190,820	5,919	54	52	NO
	08/13/08	13:00	NA	3,821,480	NA	23	2,193,216	22	2,216,126	6,015	52	50	NO
	08/15/08	12:15	NA	3,896,580	NA	20	2,239,564	20	2,260,154	6,138	52	50	NO
18	08/18/08	13:30	NA	4,039,140	NA	28	2,323,321	29	2,342,872	6,366	56	50	NO
	08/20/08	13:00	NA	4,158,930	NA	33	2,393,336	34	2,415,657	6,560	50	48	NO
	08/22/08	12:10	NA	4,257,790	NA	18	2,448,485	19	2,475,464	6,717	54	52	NO
19	08/25/08	12:15	NA	4,257,790	NA	20	2,530,127	21	2,562,514	6,947	50	48	A
	08/27/08	11:00	NA	4,500,780	NA	23	2,595,116	25	2,612,857	7,105	50	48	NO
	08/29/08	12:15	NA	4,565,660	NA	21	2,639,811	20	2,645,293	7,210	46	44	NO
20	09/02/08	16:30	NA	4,851,930	NA	10	2,813,162	10	2,805,289	7,665	48	46	NO
	09/05/08	17:00	NA	4,914,310	NA	8	2,849,931	8	2,840,155	7,762	48	46	NO
21	09/08/08	13:00	NA	5,012,540	NA	18	2,908,667	17	2,896,183	7,919	50	48	NO
	09/12/08	18:00	NA	5,140,830	NA	22	2,976,935	20	2,970,448	8,113	52	50	NO
22	09/15/08	13:30	NA	5,228,760	NA	11	3,028,068	12	3,026,130	8,259	50	48	NO
	09/17/08	12:00	NA	5,289,580	NA	16	3,060,203	17	3,062,115	8,352	52	50	NO
	09/19/08	18:00	NA	5,351,010	NA	13	3,093,696	14	3,099,272	8,448	54	52	NO
23	09/22/08	13:00	NA	5,457,210	NA	0	3,154,143	0	3,168,543	8,625	48	46	NO
	09/24/08	13:00	366.9	5,529,180	NA	7	3,194,471	8	3,207,454	8,733	48	46	NO
	09/26/08	12:00	370.4	5,599,680	336	13	3,233,311	14	3,246,594	8,840	48	46	NO
24	09/29/08	13:00	377.4	5,709,200	261	9	3,298,673	9	3,315,349	9,023	50	48	NO
	10/01/08	11:00	385.2	5,741,180	68	11	3,333,545	11	3,356,069	9,126	56	54	NO
	10/03/08	12:30	392.9	5,841,820	218	18	3,374,093	18	3,398,612	9,239	54	52	NO
25	10/06/08	10:00	401.2	5,948,520	214	12	3,436,239	11	3,462,832	9,412	56	54	NO
	10/08/08	13:30	406.1	6,013,080	220	10	3,472,448	9	3,500,493	9,512	60	58	A/B
	10/10/08	12:00	411.1	6,077,220	214	15	3,506,509	14	3,536,656	9,608	56	54	NO
26	10/13/08	10:30	419.3	6,182,830	215	41	3,566,686	42	3,601,689	9,779	50	48	NO
	10/15/08	11:00	424.6	6,251,860	217	16	3,606,724	17	3,646,687	9,895	52	50	NO
	10/17/08	12:15	428.7	6,313,910	252	48	3,640,690	49	3,682,222	9,990	58	56	NO
27	10/22/08	11:00	439.1	6,446,350	212	10	3,715,088	11	3,763,150	10,202	56	54	NO
	10/24/08	11:50	441.7	6,540,090	NA	20	3,766,512	21	3,819,683	10,349	60	58	NO
28	10/27/08	11:50	454.9	6,643,080	130	13	3,824,881	14	3,881,097	10,512	56	54	NO
	10/29/08	11:00	459.7	6,706,080	219	11	3,860,078	12	3,918,034	10,611	50	48	NO
	10/31/08	11:50	464.4	6,767,480	218	11	3,894,288	12	3,954,467	10,707	52	50	NO
29	11/03/08	12:00	473.2	6,879,620	212	9	3,957,697	10	4,023,236	10,887	48	46	NO
	11/05/08	11:00	478.0	6,942,750	219	11	3,992,801	12	4,061,902	10,988	50	48	NO
	11/07/08	13:30	482.9	7,005,330	213	13	4,026,566	14	4,098,957	11,085	56	54	NO
30	11/10/08	10:35	490.2	7,101,060	219	9	4,080,056	9	4,156,842	11,237	52	50	NO
	11/14/08	10:40	499.4	7,220,500	216	11	4,145,901	12	4,227,587	11,423	52	50	NO
31	11/17/08	09:00	507.3	7,321,750	214	15	4,202,448	16	4,287,565	11,582	50	48	NO
	11/19/08	10:00	512.3	7,386,980	217	14	4,236,661	14	4,324,283	11,679	48	46	A/B
	11/21/08	10:50	517.1	7,449,280	216	12	4,272,209	13	4,361,633	11,778	60	58	NO
32	11/24/08	10:00	524.8	7,548,080	214	9	4,327,859	10	4,420,702	11,935	58	56	NO
	11/26/08	10:00	529.6	7,610,590	217	12	4,365,056	13	4,460,132	12,039	56	54	NO
	11/28/08	11:00	534.0	7,668,040	218	18	4,397,278	20	4,494,546	12,130	52	50	NO
33	12/01/08	09:00	542.2	7,775,300	218	18	4,458,196	19	4,559,130	12,301	54	52	NO

**Table A-1. EPA Arsenic Demonstration Project at Geneseo Hills Subdivision in Geneseo, IL - Daily System Operation Log Sheet
(Continued)**

Week No.	Date	Time	Supply Well (No.5)			Vessel A		Vessel B		System			Vessel Back-wash
			Adjusted Pump Hours ^(a)	Adjusted Totalizer Meter	Avg Flowrate to Tanks	Instant Flowrate A	Cum. Flow Totalizer A	Instant Flowrate B	Cum. Flow Totalizer B	Cum. Bed Volume (A + B)	Inlet Pressure	Outlet Pressure	
			hr	gal	gpm	gpm	gal	gpm	gal	BV	psi	psi	
34	12/03/08	09:00	546.7	7,834,130	218	16	4,490,245	17	4,593,527	12,392	56	54	NO
	12/05/08	10:00	551.7	7,899,180	217	16	4,526,906	16	4,631,771	12,494	60	58	NO
	12/08/08	10:00	559.4	7,999,480	217	9	4,583,831	8	4,691,684	12,653	56	54	NO
	12/10/08	10:00	564.7	8,072,780	231	18	4,626,153	19	4,736,717	12,773	60	58	NO
	12/12/08	09:50	569.6	8,132,420	203	12	4,658,576	13	4,769,404	12,861	56	54	NO
35	12/15/08	12:00	577.6	8,235,700	215	19	4,716,241	20	4,834,682	13,029	60	58	NO
	12/17/08	13:30	582.8	8,302,830	215	9	4,751,721	10	4,873,119	13,130	51	49	A/B
	12/19/08	10:30	585.1	8,331,130	205	10	4,768,016	11	4,890,336	13,176	50	48	NO
36	12/22/08	09:00	595.7	8,469,340	217	24	4,848,763	25	4,977,320	13,405	54	52	NO
	12/26/08	11:00	606.1	8,607,030	221	22	4,928,948	23	5,062,931	13,631	51	49	NO
37	12/29/08	09:30	613.8	8,708,520	220	51	4,987,215	49	5,124,307	13,794	55	53	NO
	12/31/08	12:00	617.9	8,773,530	264	35	5,024,398	33	5,163,655	13,898	60	58	NO
	01/02/09	10:00	624.3	8,846,800	191	18	5,067,104	19	5,208,867	14,018	52	50	NO
38	01/05/09	09:00	632.5	8,954,350	219	18	5,128,811	18	5,273,729	14,191	56	54	NO
	01/07/09	11:45	637.1	9,014,380	218	10	5,163,340	11	5,310,185	14,288	50	48	NO
	01/09/09	13:45	642.1	9,079,300	216	13	5,199,858	14	5,348,621	14,390	54	52	NO
39	01/12/09	09:00	650.0	9,187,380	228	6	5,258,994	7	5,410,427	14,555	52	50	NO
	01/14/09	11:30	654.8	9,244,190	197	19	5,294,726	20	5,447,977	14,655	58	56	NO
	01/16/09	11:45	660.4	9,316,990	217	15	5,333,683	15	5,492,012	14,768	56	54	NO
40	01/21/09	09:00	672.5	9,478,040	222	11	5,427,695	12	5,588,052	15,027	50	48	A/B
	01/23/09	12:00	677.6	9,546,620	224	13	5,462,192	14	5,624,436	15,124	56	54	NO
41	01/26/09	12:00	685.4	9,642,160	204	8	5,520,982	9	5,687,420	15,290	52	50	NO
	01/28/09	12:20	689.6	9,715,080	289	12	5,553,441	13	5,722,449	15,382	51	49	NO
	01/30/09	11:00	694.4	9,764,530	172	12	5,588,122	13	5,760,102	15,481	56	54	NO
42	02/02/09	15:30	702.6	9,871,040	216	15	5,649,507	16	5,824,796	15,653	51	49	NO
	02/04/09	14:30	707.4	9,934,710	221	15	5,685,125	16	5,862,821	15,754	52	50	NO
	02/06/09	15:15	712.4	10,000,780	220	12	5,722,790	13	5,902,725	15,859	54	52	NO
43	02/09/09	15:45	720.5	10,105,580	216	13	5,782,806	14	5,966,427	16,028	54	52	NO
	02/11/09	14:30	725.3	10,168,060	217	12	5,817,782	13	6,003,516	16,126	52	50	NO
	02/13/09	15:40	730.3	10,233,210	217	15	5,855,984	16	6,043,801	16,233	52	50	NO
44	02/16/09	14:45	738.5	10,339,090	215	18	5,918,686	19	6,109,042	16,408	54	52	NO
	02/18/09	15:00	744.7	10,420,240	218	19	5,962,873	20	6,154,604	16,530	56	54	A/B
	02/20/09	16:00	749.9	10,465,240	144	10	6,001,506	11	6,195,617	16,639	54	52	NO
45	02/23/09	15:00	759.6	10,612,880	254	19	6,077,284	20	6,276,292	16,853	60	58	NO
	02/25/09	15:00	765.7	10,692,030	216	20	6,123,968	21	6,325,794	16,984	52	50	NO
	02/27/09	15:45	772.2	10,775,830	215	35	6,174,241	36	6,378,542	17,124	55	53	NO
46	03/02/09	14:30	783.2	10,918,450	216	15	6,257,379	16	6,466,225	17,357	52	50	NO
	03/06/09	15:30	798.3	11,112,580	214	17	6,371,151	18	6,586,310	17,676	56	54	NO
47	03/09/09	15:00	809.7	11,258,550	213	18	6,456,970	18	6,676,707	17,917	50	48	NO
	03/11/09	15:00	817.3	11,359,250	221	17	6,515,408	18	6,738,056	18,080	56	54	NO
	03/13/09	15:00	825.0	11,456,170	210	19	6,572,508	20	6,797,763	18,239	50	48	NO
48	03/16/09	15:00	838.6	11,630,730	214	23	6,673,354	24	6,902,983	18,521	54	52	NO
	03/18/09	15:00	847.5	11,744,800	214	32	6,738,294	34	6,970,432	18,701	48	46	A/B
	03/20/09	09:00	855.6	11,849,830	216	22	6,797,702	23	7,033,847	18,869	52	50	NO
49	03/23/09	15:00	870.7	12,041,580	212	35	6,909,881	36	7,153,232	19,185	58	56	NO
	03/26/09	09:00	877.8	12,209,230	394	0	7,006,235	0	7,255,332	19,455	54	52	NO

**Table A-1. EPA Arsenic Demonstration Project at Geneseo Hills Subdivision in Geneseo, IL - Daily System Operation Log Sheet
(Continued)**

Week No.	Date	Time	Supply Well (No.5)			Vessel A		Vessel B		System			Vessel Back-wash
			Adjusted Pump Hours ^(a)	Adjusted Totalizer Meter	Avg Flowrate to Tanks	Instant Flowrate A	Cum. Flow Totalizer A	Instant Flowrate B	Cum. Flow Totalizer B	Cum. Bed Volume (A + B)	Inlet Pressure	Outlet Pressure	
			hr	gal	gpm	gpm	gal	gpm	gal	BV	psi	psi	
50	03/27/09	09:00	879.1	12,238,620	377	15	7,022,353	16	7,273,190	19,502	54	52	NO
	03/30/09	15:00	894.7	12,352,330	121	13	7,087,171	14	7,342,919	19,685	54	52	NO
	04/01/09	15:00	901.0	12,433,780	215	17	7,135,226	18	7,394,007	19,821	52	50	NO
	04/04/09	09:00	911.2	12,463,680	NA	27	7,211,799	29	7,474,860	20,035	50	48	NO
51	04/06/09	09:00	919.6	12,673,280	416	25	7,275,629	26	7,542,047	20,214	60	58	NO
	04/08/09	09:00	927.2	12,772,330	217	20	7,334,630	22	7,604,119	20,379	50	48	NO
	04/10/09	09:00	940.0	12,932,480	209	74	7,423,763	82	7,699,879	20,631	56	54	NO
52	04/13/09	09:00	951.2	13,067,110	200	11	7,498,201	12	7,781,357	20,844	50	48	NO
	04/15/09	09:00	956.4	13,134,340	215	6	7,536,876	5	7,815,776	20,944	54	52	NO
	04/17/09	09:00	960.7	13,190,760	219	8	7,574,638	0	7,842,014	21,031	54	52	NO
53	04/20/09	09:00	968.4	13,291,220	217	10	7,641,266	9	7,891,570	21,190	54	52	NO
	04/22/09	09:00	973.0	13,368,780	281	9	7,680,604	9	7,923,015	21,286	54	52	A/B
	04/24/09	09:00	978.1	13,417,240	158	14	7,713,576	15	7,958,182	21,379	48	46	NO
54	04/27/09	09:00	986.0	13,498,380	171	12	7,773,379	12	8,022,079	21,548	54	52	NO
	04/29/09	09:00	990.5	13,580,320	303	15	7,806,061	15	8,056,971	21,640	56	54	NO
	05/01/09	09:00	995.6	13,646,800	217	16	7,843,181	17	8,096,503	21,745	56	54	NO
55	05/04/09	09:00	1003.3	13,748,460	220	16	7,900,866	17	8,157,332	21,906	48	46	NO
	05/06/09	09:00	1008.5	13,815,780	216	18	7,938,766	18	8,196,560	22,012	48	46	NO
	05/08/09	09:00	1013.2	13,877,380	218	0	7,972,413	0	8,231,105	22,105	52	50	NO
56	05/11/09	09:00	1021.3	13,984,000	219	9	8,032,225	10	8,293,515	22,271	50	48	NO
	05/16/09	09:00	1034.1	14,145,750	211	15	8,121,611	16	8,386,449	22,520	54	52	NO
	05/18/09	09:00	1039.2	14,218,780	239	9	8,164,536	9	8,429,904	22,638	50	48	NO
57	05/20/09	09:00	1044.6	14,288,580	215	12	8,202,197	13	8,468,391	22,742	58	56	A/B
	05/22/09	09:00	1050.5	14,364,410	214	24	8,244,172	25	8,514,080	22,861	48	46	NO
	05/27/09	09:00	1067.4	14,584,580	217	13	8,369,136	14	8,647,654	23,214	48	46	NO
58	05/29/09	09:00	1074.4	14,676,180	218	19	8,421,230	20	8,702,316	23,360	50	48	NO
	06/01/09	09:00	1081.5	14,768,530	217	0	8,472,861	0	8,756,658	23,504	58	56	NO
	06/04/09	09:00	1088.5	14,860,050	218	12	8,524,731	13	8,810,414	23,648	50	48	NO
59	06/05/09	09:00	1091.5	14,900,130	223	16	8,548,091	17	8,834,566	23,713	48	46	NO
	06/08/09	09:00	1101.2	15,025,520	215	27	8,620,804	28	8,910,136	23,915	52	50	NO
	06/10/09	10:00	1106.2	15,095,580	234	20	8,659,573	21	8,950,512	24,023	46	44	NO
60	06/12/09	09:00	1111.7	15,163,650	206	14	8,701,196	15	8,994,194	24,140	54	52	NO
	06/15/09	09:00	1120.0	15,272,180	218	11	8,763,546	11	9,058,892	24,313	50	48	NO
	06/17/09	10:00	1125.1	15,339,880	221	21	8,802,556	22	9,099,457	24,422	52	50	NO
61	06/19/09	11:00	1130.4	15,408,920	217	22	8,842,532	23	9,140,700	24,532	48	46	NO
	06/22/09	09:00	1138.4	15,512,680	216	38	8,902,370	39	9,202,540	24,698	54	52	NO
	06/24/09	13:00	1144.3	15,591,330	222	18	8,947,764	20	9,249,945	24,825	50	48	A/B
62	06/26/09	09:00	1150.2	15,668,380	218	35	8,990,472	36	9,294,969	24,945	52	50	NO
	06/29/09	09:00	1159.7	15,792,390	218	16	9,064,186	17	9,372,757	25,151	48	46	NO
	07/01/09	10:00	1165.3	15,866,880	222	18	9,107,850	19	9,417,335	25,272	54	52	NO
63	07/03/09	09:30	1171.2	15,943,700	217	34	9,154,018	36	9,463,717	25,398	46	44	NO
	07/08/09	11:00	1186.1	16,137,400	217	12	9,267,822	13	9,578,538	25,710	46	44	NO
	07/10/09	09:00	1191.3	16,205,280	218	16	9,307,111	17	9,618,373	25,818	52	50	NO
64	07/13/09	15:00	1200.9	16,308,820	180	17	9,367,734	18	9,680,294	25,985	54	52	NO
	07/15/09	12:00	1206.1	16,377,580	220	10	9,408,158	10	9,720,699	26,095	50	48	NO
	07/17/09	10:00	1210.5	16,435,680	220	19	9,441,633	20	9,754,133	26,187	51	49	NO

**Table A-1. EPA Arsenic Demonstration Project at Geneseo Hills Subdivision in Geneseo, IL - Daily System Operation Log Sheet
(Continued)**

Week No.	Date	Time	Supply Well (No.5)			Vessel A		Vessel B		System			Vessel Back-wash
			Adjusted Pump Hours ^(a)	Adjusted Totalizer Meter	Avg Flowrate to Tanks	Instant Flowrate A	Cum. Flow Totalizer A	Instant Flowrate B	Cum. Flow Totalizer B	Cum. Bed Volume (A + B)	Inlet Pressure	Outlet Pressure	
			hr	gal	gpm	gpm	gal	gpm	gal	BV	psi	psi	
66	07/20/09	09:30	1217.7	16,530,040	218	14	9,495,888	15	9,808,895	26,335	48	46	NO
	07/22/09	12:00	1222.5	16,593,690	221	12	9,532,555	13	9,845,994	26,436	48	46	A/B
	07/24/09	09:00	1227.3	16,655,440	214	21	9,566,166	22	9,881,247	26,530	52	50	NO
67	07/27/09	10:00	1234.7	16,753,180	220	15	9,624,737	16	9,941,684	26,692	48	46	NO
	07/29/09	09:45	1239.4	16,815,080	220	14	9,661,206	14	9,977,352	26,791	54	52	NO
	07/31/09	10:00	1244.2	16,877,840	218	18	9,698,270	19	10,013,362	26,890	50	48	NO
68	08/03/09	16:00	1251.6	16,975,980	221	15	9,755,971	16	10,069,067	27,045	48	46	NO
	08/05/09	13:45	1257.2	17,050,480	222	52	9,798,926	53	10,110,452	27,160	44	40	NO
	08/07/09	10:00	1262.1	17,111,960	209	11	9,836,241	10	10,146,567	27,260	50	48	NO
69	08/10/09	09:00	1269.2	17,206,140	221	14	9,891,641	14	10,199,802	27,408	48	46	NO
	08/12/09	10:00	1273.8	17,266,880	220	20	9,928,131	19	10,234,202	27,505	44	42	NO
	08/14/09	09:00	1279.2	17,337,540	218	18	9,970,132	17	10,274,457	27,617	46	44	NO
70	08/17/09	09:30	1286.5	17,434,280	221	14	10,027,494	13	10,329,684	27,771	50	48	NO
	08/21/09	11:00	1295.5	17,552,330	219	13	10,096,812	12	10,396,081	27,956	48	46	NO
71	08/24/09	10:00	1303.0	17,651,140	220	12	10,153,800	11	10,453,239	28,112	50	48	NO
	08/26/09	10:30	1308.0	17,715,780	215	14	10,188,358	15	10,488,625	28,207	50	48	A/B
	08/28/09	09:30	1311.9	17,767,840	222	8	10,217,686	7	10,519,542	28,289	45	43	NO
72	08/31/09	09:00	1318.9	17,859,950	219	9	10,268,897	10	10,573,014	28,432	54	52	NO
	09/02/09	10:30	1323.0	17,914,320	221	11	10,298,081	12	10,603,126	28,513	56	54	NO
	09/04/09	10:00	1327.4	17,972,630	221	14	10,330,941	15	10,636,872	28,604	44	42	NO
73	09/09/09	11:00	1340.6	18,144,340	217	10	10,427,766	10	10,735,562	28,871	48	46	NO
	09/11/09	10:00	1345.0	18,202,930	222	12	10,460,822	12	10,768,958	28,961	46	44	NO
	09/14/09	11:00	1352.9	18,306,150	218	10	10,519,530	9	10,828,763	29,123	46	44	NO
74	09/16/09	13:00	1358.5	18,379,340	218	16	10,561,975	16	10,871,597	29,239	48	46	NO
	09/18/09	09:30	1363.1	18,439,920	219	15	10,596,156	14	10,905,829	29,333	50	48	NO
	09/21/09	11:00	1371.0	18,542,010	215	8	10,655,090	7	10,964,550	29,493	48	46	NO
75	09/25/09	15:30	1380.1	18,662,590	221	16	10,723,738	15	11,031,949	29,679	50	48	NO
	09/28/09	09:30	1386.5	18,746,640	219	0	10,771,609	0	11,079,420	29,809	50	48	NO
	09/30/09	10:30	1391.3	18,809,050	217	9	10,807,364	8	11,114,371	29,905	52	50	A/B
76	10/02/09	10:00	1395.9	18,868,760	216	18	10,838,358	20	11,147,231	29,992	52	50	NO
	10/12/09	15:00	1420.3	19,189,580	219	11	11,018,109	11	11,331,097	30,488	50	48	NO
	10/14/09	10:00	1424.5	19,245,280	221	22	11,048,844	18	11,362,340	30,573	58	56	NO
77	10/16/09	09:30	1428.8	19,302,980	224	0	11,085,406	0	11,393,420	30,665	50	48	NO
	10/19/09	10:00	1435.9	19,395,500	217	12	11,139,569	12	11,445,034	30,810	58	56	NO
	10/21/09	10:00	1440.5	19,456,920	223	12	11,174,149	12	11,479,281	30,903	56	54	A/B
78	10/23/09	10:30	1445.3	19,519,450	217	16	11,208,716	17	11,513,829	30,998	48	46	NO
	10/26/09	09:30	1452.6	19,616,180	221	11	11,261,746	11	11,570,812	31,148	50	48	NO
	10/28/09	10:00	1457.6	19,681,120	216	13	11,298,678	14	11,609,082	31,250	50	48	NO
79	10/30/09	09:30	1466.0	19,788,040	212	86	11,359,941	102	11,675,183	31,424	40	21	NO
	11/02/09	17:35	1475.7	19,909,790	209	15	11,416,126	15	11,733,752	31,581	51	49	NO
	11/04/09	09:20	1480.2	19,968,600	218	9	11,451,437	9	11,770,072	31,678	50	48	NO
80	11/06/09	10:00	1485.0	20,033,050	224	18	11,489,310	18	11,808,353	31,782	50	48	NO
	11/09/09	10:00	1494.5	20,142,620	192	16	11,552,996	17	11,872,692	31,957	56	54	NO
	11/11/09	16:00	1502.4	20,221,480	166	9	11,600,086	9	11,920,425	32,086	52	50	NO
81	11/13/09	09:00	1504.3	20,273,730	458	24	11,629,830	25	11,945,162	32,161	52	50	NO
	11/16/09	09:30	1510.9	20,361,530	222	10	11,679,160	12	11,998,499	32,301	52	50	NO

**Table A-1. EPA Arsenic Demonstration Project at Geneseo Hills Subdivision in Geneseo, IL - Daily System Operation Log Sheet
(Continued)**

Week No.	Date	Time	Supply Well (No.5)			Vessel A		Vessel B		System			Vessel Back-wash
			Adjusted Pump Hours ^(a)	Adjusted Totalizer Meter	Avg Flowrate to Tanks	Instant Flowrate A	Cum. Flow Totalizer A	Instant Flowrate B	Cum. Flow Totalizer B	Cum. Bed Volume (A + B)	Inlet Pressure	Outlet Pressure	
			hr	gal	gpm	gpm	gal	gpm	gal	BV	psi	psi	
83	11/18/09	09:00	1515.2	20,419,180	223	8	11,711,895	9	12,031,038	32,390	58	56	NO
	11/20/09	10:00	1519.5	20,478,140	229	8	11,744,988	9	12,063,910	32,480	50	48	NO
	11/23/09	12:00	1526.5	20,572,540	225	14	11,799,169	14	12,119,111	32,629	50	48	NO
	11/25/09	12:00	1530.9	20,632,880	229	9	11,832,908	10	12,153,445	32,722	54	52	NO
	11/27/09	11:00	1535.3	20,692,220	225	17	11,866,821	18	12,187,497	32,814	52	50	NO
84	11/30/09	10:00	1542.4	20,786,900	222	16	11,920,458	17	12,241,517	32,961	50	48	NO
	12/02/09	10:30	1546.2	20,840,980	237	9	11,950,469	10	12,271,388	33,043	54	52	NO
	12/04/09	09:30	1550.2	20,896,290	230	11	11,981,332	10	12,301,696	33,126	50	48	NO
85	12/07/09	12:00	1557.1	20,989,930	226	9	12,035,736	10	12,354,765	33,273	50	48	NO
	12/11/09	10:00	1565.4	21,102,260	226	8	12,100,089	9	12,418,385	33,448	48	46	NO
	12/14/09	15:30	1572.8	21,195,580	210	15	12,150,973	16	12,469,952	33,587	56	54	NO
86	12/16/09	10:00	1577.0	21,250,820	219	11	12,182,439	11	12,501,448	33,673	50	48	NO
	12/18/09	10:00	1581.4	21,308,590	219	27	12,214,386	28	12,533,298	33,760	54	52	NO
	12/21/09	09:30	1588.3	21,399,030	218	17	12,265,451	18	12,585,032	33,901	48	46	NO
87	12/23/09	10:00	1593.0	21,460,910	219	15	12,300,531	16	12,621,202	33,998	56	54	NO
	12/28/09	10:00	1605.1	21,619,650	219	23	12,391,021	24	12,713,832	34,248	50	48	NO
88	01/01/10	12:00	1614.6	21,744,380	219	18	12,462,393	18	12,786,983	34,445	60	58	NO
	01/04/10	10:00	1622.5	21,848,980	221	12	12,510,604	13	12,836,056	34,577	52	50	NO
	01/06/10	11:00	1627.4	21,913,260	219	13	12,558,814	14	12,885,128	34,710	58	56	NO
	01/08/10	10:00	1632.0	21,973,910	220	20	12,593,787	21	12,920,768	34,806	48	46	NO
89	01/11/10	11:30	1645.3	22,141,880	210	36	12,689,828	37	13,018,443	35,071	48	46	NO
	01/13/10	10:00	1655.3	22,266,680	208	10	12,760,509	11	13,090,465	35,265	52	50	NO
	01/15/10	10:00	1659.9	22,326,930	218	9	12,793,255	10	13,123,479	35,355	58	56	A/B
	01/18/10	09:45	1666.7	22,417,800	223	12	12,846,030	13	13,177,506	35,501	56	54	NO
90	01/22/10	10:00	1675.4	22,532,800	220	10	12,910,687	11	13,243,733	35,679	58	56	NO
	01/25/10	15:30	1682.8	22,631,100	221	11	12,966,514	11	13,301,100	35,834	50	48	NO
	01/27/10	10:00	1687.3	22,690,640	221	17	13,000,576	17	13,335,708	35,927	52	50	NO
	01/29/10	10:00	1692.3	22,756,230	219	16	13,038,996	17	13,374,242	36,032	54	52	NO
91	02/01/10	10:00	1701.4	22,875,480	218	17	13,109,571	17	13,445,315	36,226	60	58	NO
	02/03/10	10:30	1707.1	22,950,320	219	8	13,155,286	8	13,491,404	36,351	52	50	NO
	02/05/10	10:00	1713.6	23,032,360	210	11	13,202,927	12	13,539,990	36,482	56	54	NO
	02/08/10	10:30	1720.7	23,126,750	222	9	13,256,771	9	13,594,862	36,631	55	53	NO
92	02/10/10	10:00	1725.0	23,183,030	218	12	13,287,997	13	13,626,797	36,717	50	48	NO
	02/12/10	10:15	1729.3	23,239,160	218	18	13,318,934	19	13,658,515	36,802	52	50	NO
	02/15/10	10:30	1736.3	23,332,430	222	13	13,372,227	13	13,711,919	36,948	52	50	NO
	02/19/10	10:00	1744.9	23,445,100	218	14	13,435,401	15	13,774,674	37,119	54	52	NO
93	02/22/10	10:00	1751.8	23,537,130	222	12	13,487,781	13	13,827,197	37,263	52	50	NO
	02/24/10	04:00	1756.4	23,596,810	216	15	13,520,747	14	13,859,934	37,352	52	50	NO
	02/26/10	12:00	1760.4	23,650,090	222	0	13,550,218	0	13,889,193	37,432	56	54	NO
	03/01/10	09:00	1767.3	23,741,400	221	0	13,602,776	0	13,941,366	37,575	50	48	NO
94	03/03/10	07:00	1771.3	23,793,850	219	16	13,631,474	16	13,970,092	37,654	52	50	NO
	03/05/10	10:30	1775.7	23,851,780	219	13	13,663,014	14	14,002,015	37,740	58	56	NO
	03/08/10	10:00	1782.3	23,938,330	219	10	13,711,941	10	14,051,150	37,874	58	56	NO
	03/10/10	10:00	1786.5	23,994,820	224	9	13,743,461	9	14,082,387	37,960	48	46	NO
95	03/12/10	10:00	1790.6	24,048,950	220	16	13,773,091	15	14,111,772	38,040	56	54	NO
	03/15/10	10:15	1797.2	24,136,080	220	16	13,822,441	15	14,160,827	38,174	58	56	NO

**Table A-1. EPA Arsenic Demonstration Project at Geneseo Hills Subdivision in Geneseo, IL - Daily System Operation Log Sheet
(Continued)**

Week No.	Date	Time	Supply Well (No.5)			Vessel A		Vessel B		System			Vessel Back-wash
			Adjusted Pump Hours ^(a)	Adjusted Totalizer Meter	Avg Flowrate to Tanks	Instant Flowrate A	Cum. Flow Totalizer A	Instant Flowrate B	Cum. Flow Totalizer B	Cum. Bed Volume (A + B)	Inlet Pressure	Outlet Pressure	
			hr	gal	gpm	gpm	gal	gpm	gal	BV	psi	psi	
100	03/17/10	10:00	1801.4	24,192,280	223	8	13,854,608	9	14,192,346	38,261	48	46	NO
	03/19/10	09:40	1805.6	24,247,250	218	13	13,884,847	13	14,222,397	38,343	54	52	NO
	03/22/10	09:00	1812.9	24,343,830	221	8	13,940,036	7	14,277,320	38,494	54	52	NO
	03/24/10	09:30	1817.1	24,398,900	219	13	13,970,349	12	14,307,276	38,576	54	52	A/B
	03/26/10	10:00	1821.7	24,460,350	223	9	14,002,651	10	14,340,433	38,665	47	45	NO
101	03/29/10	10:00	1827.7	24,540,180	222	14	14,048,914	15	14,388,305	38,794	50	48	NO
	03/31/10	10:00	1831.8	24,594,030	219	26	14,078,866	27	14,414,139	38,870	56	54	NO
	04/02/10	09:00	1836.2	24,652,620	222	22	14,111,271	23	14,453,758	38,968	52	50	NO
102	04/05/10	09:30	1843.2	24,744,540	219	15	14,162,271	16	14,507,492	39,111	50	48	NO
	04/07/10	09:30	1848.0	24,808,130	221	0	14,197,783	0	14,544,872	39,210	48	46	NO
	04/09/10	09:30	1852.9	24,863,630	189	0	14,227,862	0	14,576,846	39,295	50	48	NO
	04/12/10	09:00	1859.6	24,961,210	243	7	14,282,492	8	14,634,275	39,448	46	44	NO
103	04/14/10	10:00	1864.3	25,023,530	221	10	14,317,411	10	14,669,768	39,544	50	48	NO
	04/16/10	10:00	1869.2	25,087,630	218	6	14,352,946	7	14,706,072	39,642	56	54	NO
104	04/19/10	09:30	1877.2	25,191,780	217	13	14,412,141	13	14,765,852	39,804	58	56	NO
	04/21/10	10:15	1882.0	25,253,200	213	19	14,448,196	20	14,802,152	39,903	52	50	NO
	04/23/10	09:00	1886.6	25,314,610	223	8	14,481,153	9	14,836,654	39,995	48	46	NO
105	04/26/10	10:00	1893.2	25,402,300	221	13	14,529,381	13	14,888,010	40,131	46	44	NO
	04/30/10	12:00	1902.9	25,528,770	217	0	14,598,890	0	14,961,136	40,325	50	48	NO
106	05/03/10	09:30	1910.9	25,632,540	216	12	14,658,426	12	15,021,368	40,489	50	48	NO
	05/05/10	10:00	1915.5	25,693,340	220	13	14,692,162	14	15,056,058	40,582	47	45	NO
	05/07/10	10:00	1920.4	25,758,050	220	14	14,728,876	14	15,093,657	40,683	48	46	NO
107	05/10/10	10:30	1928.1	25,858,500	217	8	14,786,877	8	15,151,874	40,842	54	52	NO
	05/12/10	10:00	1932.6	25,916,640	215	10	14,819,613	10	15,184,801	40,931	48	46	NO
	05/14/10	17:00	1937.4	25,979,290	218	17	14,854,562	16	15,219,404	41,026	52	50	NO
108	05/17/10	12:30	1944.7	26,074,680	218	8	14,909,886	8	15,273,983	41,176	48	46	NO
	05/19/10	16:00	1949.6	26,139,840	222	15	14,946,388	15	15,310,946	41,277	48	46	NO
	05/21/10	09:00	1954.1	26,199,120	220	16	14,980,016	16	15,345,082	41,369	54	52	NO
109	05/24/10	16:00	1964.8	26,336,950	215	19	15,060,834	19	15,425,427	41,589	46	44	NO
	05/26/10	10:00	1970.1	26,406,280	218	9	15,089,803	9	15,464,238	41,681	46	44	NO
	05/28/10	13:10	1975.8	26,479,930	215	13	15,143,588	13	15,506,010	41,812	52	50	NO
110	06/02/10	10:00	1990.4	26,669,840	217	0	15,254,836	0	15,614,552	42,111	46	44	NO
	06/04/10	11:00	1994.6	26,773,330	411	8	15,287,090	9	15,645,597	42,198	51	49	NO
111	06/07/10	14:00	2002.6	26,830,680	119	21	15,348,311	22	15,704,872	42,362	48	46	NO
	06/09/10	10:00	2006.5	26,882,880	223	23	15,378,931	23	15,734,342	42,444	50	48	NO
	06/11/10	09:00	2011.0	26,941,710	218	12	15,414,074	12	15,767,987	42,538	44	42	A/B
112	06/14/10	09:45	2018.2	27,035,880	218	19	15,466,256	20	15,820,612	42,681	56	54	NO
	06/16/10	12:00	2026.8	27,097,030	119	25	15,502,921	25	15,857,937	42,782	50	48	NO
	06/18/10	10:00	2026.9	27,151,280	NA	17	15,534,673	18	15,890,334	42,869	42	40	NO
113	06/21/10	10:00	2034.6	27,255,930	227	11	15,593,958	12	15,950,452	43,032	42	40	NO
	06/23/10	09:30	2039.4	27,317,090	212	15	15,630,796	16	15,988,090	43,134	44	42	NO
	06/25/10	08:30	2050.0	27,326,130	NA	40	15,654,911	41	16,013,002	43,201	48	46	NO
114	06/28/10	12:00	2060.2	27,459,500	218	13	15,733,146	13	16,093,182	43,417	50	48	NO
	06/30/10	12:00	2066.4	27,538,590	213	11	15,780,202	11	16,140,817	43,546	42	40	NO
	07/02/10	09:45	2072.2	27,616,760	225	16	15,825,786	16	16,186,727	43,671	50	48	NO
115	07/05/10	07:00	2081.3	27,735,680	218	17	15,895,236	17	16,256,332	43,861	52	50	NO

**Table A-1. EPA Arsenic Demonstration Project at Geneseo Hills Subdivision in Geneseo, IL - Daily System Operation Log Sheet
(Continued)**

Week No.	Date	Time	Supply Well (No.5)			Vessel A		Vessel B		System			Vessel Back-wash
			Adjusted Pump Hours ^(a)	Adjusted Totalizer Meter	Avg Flowrate to Tanks	Instant Flowrate A	Cum. Flow Totalizer A	Instant Flowrate B	Cum. Flow Totalizer B	Cum. Bed Volume (A + B)	Inlet Pressure	Outlet Pressure	
			hr	gal	gpm	gpm	gal	gpm	gal	BV	psi	psi	
116	07/07/10	09:00	2086.5	27,806,630	227	10	15,935,319	10	16,296,695	43,970	42	40	NO
	07/09/10	12:00	2091.9	27,875,530	213	11	15,974,701	11	16,337,007	44,079	48	46	NO
	07/12/10	09:00	2099.8	27,979,180	219	21	16,036,756	22	16,400,222	44,250	55	53	NO
	07/14/10	17:00	2106.2	28,063,500	220	21	16,087,651	22	16,451,334	44,389	44	42	NO
	07/16/10	10:30	2110.8	28,124,010	219	16	16,123,749	16	16,486,782	44,487	44	42	NO
117	07/21/10	09:00	2125.1	28,311,840	219	14	16,234,531	14	16,595,057	44,786	44	42	NO
	07/23/10	10:00	2130.6	28,384,380	220	14	16,277,626	15	16,630,505	44,893	46	44	NO
118	07/26/10	12:00	2137.4	28,473,750	219	10	16,323,721	10	16,681,777	45,026	50	48	NO
	07/28/10	11:30	2142.4	28,539,380	219	17	16,362,937	17	16,719,882	45,131	44	42	NO
	07/30/10	10:30	2147.3	28,604,680	222	12	16,401,436	12	16,756,827	45,234	52	50	NO

NA = not available

1 BV = 49 ft³ = 367 gal with system in parallel configuration.

(a) Hour meter installed on September 26, 2008. Pump hours from May 8, 2009, through September 25, 2009, used to estimate total pump hours from May 8, 2008, through September 25, 2008.

(b) Updated cumulative flow totalizer calculations to reflect cumulative reading from treatment system.

(c) Operator on vacation during week of October 5, 2009.

APPENDIX B
ANALYTICAL DATA

Table B-1. Analytical Results from Treatment Plant Sampling at Geneseo Hills Subdivision, Geneseo, IL

Sampling Date		05/18/08 ^(a,b)				06/19/08 ^(c)				07/01/08				07/15/08 ^(c,d)				07/22/08		
Sampling Location	Parameter Unit	IN	AC	TA	TB	IN	AC	TA	TB	IN	AC	TA	TB	IN	AC	TA	TB	IN	AC	TT
Bed Volume	10 ³	-	-	1.3	1.4	-	-	2.9	3.0	-	-	3.8	3.8	-	-	4.7	4.8	-	-	5.2
Alkalinity (as CaCO ₃)	mg/L	374	374	374	370	384	386	382	382	366	370	375	375	374	372	372	374	378	371	378
Ammonia (as N)	mg/L	1.2	0.9	0.9	0.9	1.0	0.8	0.8	0.9	1.2	0.9	0.9	1.0	1.3	1.0	1.0	1.1	1.6	1.0	1.1
Fluoride	mg/L	0.4	0.4	0.3	0.3	-	-	-	-	0.2	0.2	0.4	0.3	-	-	-	-	0.3	0.3	0.4
Sulfate	mg/L	<0.1	0.3	0.3	0.3	-	-	-	-	<0.1	0.3	0.3	0.3	-	-	-	-	<0.1	0.3	0.3
Nitrate (as N)	mg/L	<0.05	<0.05	<0.05	<0.05	-	-	-	-	<0.05	<0.05	<0.05	<0.05	-	-	-	-	<0.05	<0.05	<0.05
P (as P)	µg/L	42.9	41.5	<10	<10	38.6	38.6	<10	<10	39.7	38.6	<10	<10	43.1	40.6	<10	<10	54.4	55.0	19.8
Silica (as SiO ₂)	mg/L	21.1	23.6	22.7	22.9	26.2	26.3	26.0	25.6	20.5	21.0	20.9	20.7	23.3	23.5	23.0	22.8	23.3	23.0	22.6
Turbidity	NTU	13.0	1.1	0.6	0.9	9.4	1.0	0.4	0.4	9.0	0.6	<0.1	<0.1	8.2	1.1	1.5	0.5	2.6	1.5	5.0
TOC	mg/L	1.6	1.6	1.2	1.2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
pH	S.U.	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	7.0	7.2	7.1
Temperature	°C	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	15.0	15.7	17.2
DO	mg/L	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
ORP	mV	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	179	230	243
Free Chlorine (as Cl ₂)	mg/L	-	NA	NA	NA	-	NA	0.5	0.5	-	NA	NA	NA	-	NA	0.7	0.7	-	0.6	0.5
Total Chlorine (as Cl ₂)	mg/L	-	NA	NA	NA	-	NA	3.2	3.2	-	NA	NA	NA	-	NA	2.9	2.9	-	3.2	2.9
Total Hardness (as CaCO ₃)	mg/L	231	230	224	225	-	-	-	-	363	361	358	360	-	-	-	-	321	312	301
Ca Hardness (as CaCO ₃)	mg/L	101	100	96.9	95.7	-	-	-	-	241	237	235	237	-	-	-	-	158	156	161
Mg Hardness (as CaCO ₃)	mg/L	130	130	127	129	-	-	-	-	122	124	123	123	-	-	-	-	163	156	140
As (total)	µg/L	22.1	22.2	0.2	0.1	18.4	18.3	1.2	1.1	19.5	19.6	0.5	0.4	20.9	20.1	0.5	0.8	17.7 ^(e)	19.9	3.3
As (soluble)	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	16.7 ^(e)	8.6	1.0
As (particulate)	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1.0 ^(e)	11.3	2.3
As(III)	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	16.6 ^(e)	0.7	0.6
As(V)	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.1 ^(e)	7.8	0.4
Fe (total)	µg/L	836	407	<25	<25	663	362	<25	<25	275	346	<25	<25	256	357	<25	<25	509	602	176
Fe (soluble)	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	410	<25	<25
Mn (total)	µg/L	10.0	6.3	0.4	0.3	8.3	5.9	3.1	1.5	5.6	6.3	6.4	4.2	5.1	5.9	8.2	7.6	7.3	7.0	8.6
Mn (soluble)	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	7.1	5.8	9.2

(a) BV from 05/19/08 system operational data.

(b) TOC samples analyzed out of hold time.

(c) Free and total chlorine measurements for TA and TB taken at TT location.

(d) BV from 07/14/08 system operational data.

(e) Samples re-analyzed for arsenic; rerun results provided in table.

Table B-1. Analytical Results from Treatment Plant Sampling at Geneseo Hills Subdivision, Geneseo, IL (Continued)

Sampling Date		08/06/08 ^(a)				08/20/08 ^(b)			09/09/08 ^(a,c)				09/24/08			10/08/08 ^(a)			
Sampling Location	Unit	IN	AC	TA	TB	IN	AC	TT	IN	AC	TA	TB	IN	AC	TT	IN	AC	TA	TB
Parameter	Unit																		
Bed Volume	10 ³	-	-	6.1	6.2	-	-	7.1	-	-	8.5	8.5	-	-	9.3	-	-	10.0	10.1
Alkalinity (as CaCO ₃)	mg/L	380	382	380	384	378	380	375	NA ^(d)	NA ^(d)	NA ^(d)	NA ^(d)	368	370	370	370	372	368	377
Ammonia (as N)	mg/L	1.4	1.0	1.0	1.0	1.3	1.0	1.0	1.3	1.1	1.0	1.0	1.3	1.1	1.1	1.3	1.1	1.1	1.1
Fluoride	mg/L	-	-	-	-	0.3	0.3	0.3	-	-	-	-	0.3	0.3	0.3	-	-	-	-
Sulfate	mg/L	-	-	-	-	<0.1	0.3	0.3	-	-	-	-	<0.1	0.3	0.3	-	-	-	-
Nitrate (as N)	mg/L	-	-	-	-	<0.05	<0.05	<0.05	-	-	-	-	<0.05	<0.05	<0.05	-	-	-	-
P (as P)	µg/L	52.1	51.9	<10	<10	20.1	24.5	<10	47.5	46.5	<10	<10	44.2	44.5	<10	49.2	49.1	<10	<10
Silica (as SiO ₂)	mg/L	23.4	22.9	23.0	23.1	24.5	24.2	24.1	23.8	24.3	24.2	24.4	24.1	22.6	23.3	23.9	24.0	23.6	24.0
Turbidity	NTU	3.1	0.6	<0.1	<0.1	5.3	0.4	0.1	4.3	0.5	<0.1	0.1	5.9	0.5	<0.1	5.4	0.5	<0.1	<0.1
TOC	mg/L	-	-	-	-	2.7	1.8	1.8	-	-	-	-	2.1	2.1	1.6	-	-	-	-
pH	S.U.	NA	NA	NA	NA	NA	7.1	7.1	NA	NA	NA	NA	7.5	7.4	7.5	NA	NA	NA	NA
Temperature	°C	NA	NA	NA	NA	NA	15.0	16.9	NA	NA	NA	NA	14.3	14.6	14.4	NA	NA	NA	NA
DO	mg/L	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	0.0	0.3	0.8	NA	NA	NA	NA
ORP	mV	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Free Chlorine (as Cl ₂)	mg/L	-	0.2	0.7	0.7	-	0.5	0.3	-	1.2	1.0	1.0	-	0.7	0.8	-	1.0	0.4	0.4
Total Chlorine (as Cl ₂)	mg/L	-	3.0	2.7	2.7	-	3.1	2.6	-	2.5	2.1	2.1	-	2.2	3.1	-	1.8	1.7	1.7
Total Hardness (as CaCO ₃)	mg/L	-	-	-	-	355	361	365	-	-	-	-	342	355	359	-	-	-	-
Ca Hardness (as CaCO ₃)	mg/L	-	-	-	-	213	213	214	-	-	-	-	214	222	226	-	-	-	-
Mg Hardness (as CaCO ₃)	mg/L	-	-	-	-	142	148	150	-	-	-	-	129	133	133	-	-	-	-
As (total)	µg/L	21.7	21.6	0.6	1.0	19.3	18.6	1.3	21.6	20.4	0.3	2.5	21.6	20.6	0.5	20.4	20.0	0.8	0.7
As (soluble)	µg/L	-	-	-	-	18.5	9.3	0.8	-	-	-	-	18.6	7.7	0.9	-	-	-	-
As (particulate)	µg/L	-	-	-	-	0.8	9.3	0.5	-	-	-	-	2.9	12.8	<0.1	-	-	-	-
As(III)	µg/L	-	-	-	-	15.5	0.5	0.5	-	-	-	-	14.5	0.3	0.6	-	-	-	-
As(V)	µg/L	-	-	-	-	3.0	8.8	0.3	-	-	-	-	4.1	7.4	0.3	-	-	-	-
Fe (total)	µg/L	962	452	<25	<25	507	354	<25	448	421	<25	32	921	394	<25	446	401	<25	<25
Fe (soluble)	µg/L	-	-	-	-	216	<25	<25	-	-	-	-	593	<25	<25	-	-	-	-
Mn (total)	µg/L	10.4	6.3	7.0	7.9	7.3	6.0	6.4	6.7	6.7	6.3	8.2	11.9	6.8	7.8	7.2	6.9	8.1	8.6
Mn (soluble)	µg/L	-	-	-	-	5.3	5.4	6.5	-	-	-	-	8.6	6.1	7.9	-	-	-	-

(a) Free and total chlorine measurements for TA and TB taken at TT location.

(b) pH and temperature measured on 09/02/08.

(c) BV from 09/08/08 system operational data.

(d) Samples out of temperature.

Table B-1. Analytical Results from Treatment Plant Sampling at Geneseo Hills Subdivision, Geneseo, IL (Continued)

Sampling Date		10/29/08			11/18/08 ^(a)				12/03/08			12/17/08				01/07/09			01/21/09			
Sampling Location	Parameter	IN	AC	TT	IN	AC	TA	TB	IN	AC	TT	IN	AC	TA	TB	IN	AC	TT	IN	AC	TA	TB
	Unit																					
Bed Volume	10 ³	-	-	11.2	-	-	12.0	12.3	-	-	13.0	-	-	13.5	13.9	-	-	14.8	-	-	15.4	15.8
Alkalinity (as CaCO ₃)	mg/L	374	370	368	371	362	369	366	380	384	384	370	374	370	374	366	348	368	372	372	370	361
		-	-	-	371	371	369	369	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Ammonia (as N)	mg/L	1.3	1.1	1.1	1.3	1.0	1.0	1.1	1.3	1.0	1.0	1.3	1.0	1.0	1.1	1.3	1.0	1.0	1.2	0.8	0.9	0.9
		-	-	-	1.3	1.0	1.0	1.0	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Fluoride	mg/L	0.3	0.3	0.3	-	-	-	-	0.3	0.3	0.3	-	-	-	-	0.4	0.3	0.9	-	-	-	-
Sulfate	mg/L	<0.1	0.3	0.3	-	-	-	-	<0.1	0.4	0.3	-	-	-	-	<0.1	0.3	0.3	-	-	-	-
Nitrate (as N)	mg/L	<0.05	<0.05	<0.05	-	-	-	-	<0.05	<0.05	<0.05	-	-	-	-	<0.05	<0.05	<0.05	-	-	-	-
P (as P)	µg/L	55.7	52.7	<10	52.5	57.6	<10	<10	67.7	70.7	<10	57.2	52.2	<10	<10	88.2	88.1	18.8	63.0	65.1	<10	<10
		-	-	-	48.6	55.8	<10	<10	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Silica (as SiO ₂)	mg/L	23.5	23.4	23.5	23.7	23.6	23.6	23.4	23.3	23.5	22.4	20.6	20.9	21.1	21.1	21.7	22.1	22.0	21.3	22.1	22.4	22.4
		-	-	-	23.4	23.4	22.8	23.3	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Turbidity	NTU	3.4	0.5	0.1	2.2	0.5	<0.1	<0.1	3.0	0.8	<0.1	13.0	4.0	1.0	2.2	2.6	0.5	0.2	13.0	0.7	<0.1	<0.1
		-	-	-	7.0	0.5	<0.1	<0.1	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TOC	mg/L	2.1	2.2	2.1	-	-	-	-	1.8	1.8	1.8	-	-	-	-	1.8	1.9	1.8	-	-	-	-
pH	S.U.	NA	NA	NA	7.4	NA	7.3	7.3	7.3	7.3	7.4	7.3	7.4	7.4	7.4	7.6	7.5	7.4	7.6	7.5	7.4	7.4
Temperature	°C	13.0	13.0	13.0	12.5	NA	12.7	12.7	12.3	12.0	12.3	10.2	11.5	10.9	11.0	11.2	11.3	11.2	11.5	11.5	11.8	11.7
DO	mg/L	2.7	4.0	3.7	4.7	NA	3.4	3.4	0.1	4.3	1.6	0.6	1.8	2.1	1.4	0.4	1.3	1.0	0.2	1.4	1.4	1.6
ORP	mV	NA	NA	NA	301	NA	297	297	720	269	263	-53	382	360	328	-60	356	374	-64	358	438	443
Free Chlorine (as Cl ₂)	mg/L	-	0.4	0.1	-	0.4	1.7	1.7	-	0.1	0.1	-	0.4	0.4	0.5	-	0.3	0.1	-	2.4	0.1	0.4
Total Chlorine (as Cl ₂)	mg/L	-	2.1	1.8	-	2.8	2.3	2.3	-	2.4	2.1	-	2.4	2.4	2.5	-	2.4	2.2	-	3.3	3.3	3.0
Total Hardness (as CaCO ₃)	mg/L	307	291	295	-	-	-	-	369	364	366	-	-	-	-	399	413	448	-	-	-	-
Ca Hardness (as CaCO ₃)	mg/L	170	162	169	-	-	-	-	219	216	216	-	-	-	-	183	178	184	-	-	-	-
Mg Hardness (as CaCO ₃)	mg/L	136	129	126	-	-	-	-	150	148	150	-	-	-	-	215	236	264	-	-	-	-
As (total)	µg/L	19.3	17.7	0.6	24.4	23.1	0.8	0.9	23.7	22.0	0.6	20.0	20.2	1.1	0.7	22.3	22.0	1.1	17.8	17.7	0.6	0.7
		-	-	-	23.0	22.8	0.8	0.9	-	-	-	-	-	-	-	-	-	-	-	-	-	-
As (soluble)	µg/L	16.8	6.9	0.4	-	-	-	-	19.0	8.9	0.6	-	-	-	-	19.0	9.2	0.8	-	-	-	-
As (particulate)	µg/L	2.5	10.8	0.3	-	-	-	-	4.8	13.1	<0.1	-	-	-	-	3.3	12.9	0.2	-	-	-	-
As(III)	µg/L	13.5	0.6	0.6	-	-	-	-	15.2	0.9	0.6	-	-	-	-	13.8	1.0	1.0	-	-	-	-
As(V)	µg/L	3.3	6.3	<0.1	-	-	-	-	3.8	8.0	<0.1	-	-	-	-	5.2	8.2	<0.1	-	-	-	-
Fe (total)	µg/L	937	356	<25	355	416	<25	<25	365	448	<25	908	403	<25	<25	259	286	<25	296	353	<25	<25
		-	-	-	251	391	<25	<25	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Fe (soluble)	µg/L	320	<25	<25	-	-	-	-	713	<25	<25	-	-	-	-	703	<25	<25	-	-	-	-
Mn (total)	µg/L	13.5	6.7	8.7	7.6	7.6	8.2	8.5	6.3	7.4	7.8	19.9	7.1	7.5	7.7	4.6	4.8	5.2	5.3	6.3	6.1	6.1
		-	-	-	7.5	7.4	8.1	8.5	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Mn (soluble)	µg/L	6.9	6.8	8.8	-	-	-	-	10.6	6.8	7.9	-	-	-	-	9.5	4.9	5.4	-	-	-	-

(a) Water quality parameters taken on 11/21/08; measurements for TA and TB taken at TT location.

Table B-1. Analytical Results from Treatment Plant Sampling at Geneseo Hills Subdivision, Geneseo, IL (Continued)

Sampling Date		02/04/09			02/18/09				03/11/09			03/18/09				04/01/09		
Sampling Location	Parameter	IN	AC	TT	IN	AC	TA	TB	IN	AC	TT	IN	AC	TA	TB	IN	AC	TT
Bed Volume	10^3	-	-	16.3	-	-	16.8	17.3	-	-	18.6	-	-	19.0	19.6	-	-	20.4
Alkalinity (as CaCO ₃)	mg/L	374	371	376	393	387	387	391	395	390	388	390	390	380	390	389	384	396
		-	-	-	-	-	-	-	-	-	-	375	380	380	375	-	-	-
Ammonia (as N)	mg/L	1.3	0.9	0.9	1.3	0.9	0.8	0.9	1.3	0.9	1.0	1.4	1.3	1.3	1.3	1.3	0.9	0.9
		-	-	-	-	-	-	-	-	-	-	1.4	1.3	1.3	1.3	-	-	-
Fluoride	mg/L	0.3	0.4	0.9	-	-	-	-	0.3	0.3	0.9	-	-	-	-	0.3	0.3	0.8
Sulfate	mg/L	<0.1	0.3	0.3	-	-	-	-	<0.1	0.3	0.3	-	-	-	-	<0.1	0.3	0.3
Nitrate (as N)	mg/L	<0.05	<0.05	<0.05	-	-	-	-	<0.05	<0.05	<0.05	-	-	-	-	<0.05	<0.05	<0.05
P (as P)	µg/L	51.7	50.6	<10	44.0	74.0	<10	<10	59.7	70.4	<10	49.1	48.2	<10	<10	53.2	51.7	<10
		-	-	-	-	-	-	-	-	-	-	48.9	48.7	<10	<10	-	-	-
Silica (as SiO ₂)	mg/L	23.5	23.6	24.1	22.0	21.5	21.2	21.7	23.2	23.6	23.2	22.8	23.1	23.3	23.3	21.3	20.9	21.1
		-	-	-	-	-	-	-	-	-	-	22.7	23.0	22.8	22.8	-	-	-
Turbidity	NTU	11.0	1.0	1.8	1.2	0.4	<0.1	<0.1	3.8	0.4	0.1	0.6	1.1	<0.1	<0.1	1.6	0.8	0.2
		-	-	-	-	-	-	-	-	-	-	0.6	1.3	<0.1	<0.1	-	-	-
TOC	mg/L	1.8	1.9	1.9	-	-	-	-	1.9	1.9	1.6	-	-	-	-	1.6	1.6	1.6
pH	S.U.	7.5	7.5	7.5	7.3	7.3	7.2	7.3	7.3	7.3	7.2	7.3	7.3	7.3	7.3	7.3	7.3	7.4
Temperature	°C	11.3	11.3	11.5	11.2	11.6	11.6	11.6	12.0	11.8	11.8	12.5	12.6	12.4	12.4	12.3	12.3	12.4
DO	mg/L	0.9	1.6	1.4	1.0	1.8	1.6	1.4	0.8	1.9	1.9	0.7	1.9	1.2	1.6	0.5	1.5	1.3
ORP	mV	-32	474	430	-14	405	423	397	-27	397	407	-26	42	71	75	-50	427	435
Free Chlorine (as Cl ₂)	mg/L	-	2.4	0.4	-	0.8	2.1	0.4	-	0.5	1.2	-	0.0	0.0	0.0	-	0.3	0.7
Total Chlorine (as Cl ₂)	mg/L	-	3.1	3.2	-	3.3	2.1	3.2	-	2.7	3.0	-	0.4	0.6	0.1	-	3.5	3.3
Total Hardness (as CaCO ₃)	mg/L	365	365	366	-	-	-	-	396	387	360	-	-	-	-	347	353	357
Ca Hardness (as CaCO ₃)	mg/L	215	215	212	-	-	-	-	210	217	214	-	-	-	-	200	205	211
Mg Hardness (as CaCO ₃)	mg/L	150	151	154	-	-	-	-	186	170	146	-	-	-	-	146	148	146
As (total)	µg/L	23.8	22.9	0.7	18.7	18.2	0.7	0.6	18.8	19.5	0.8	19.3	19.0	0.2	0.5	18.5	18.6	0.8
		-	-	-	-	-	-	-	-	-	-	17.1	16.6	0.2	0.5	-	-	-
As (soluble)	µg/L	18.8	8.9	0.8	-	-	-	-	18.0	11.8	0.7	-	-	-	-	18.3	11.9	0.7
As (particulate)	µg/L	4.9	14.1	<0.1	-	-	-	-	0.8	7.7	<0.1	-	-	-	-	0.2	6.7	<0.1
As(III)	µg/L	15.0	0.6	0.5	-	-	-	-	15.7	0.6	0.5	-	-	-	-	11.4	0.7	0.6
As(V)	µg/L	3.9	8.3	0.2	-	-	-	-	2.3	11.2	0.2	-	-	-	-	6.9	11.2	<0.1
Fe (total)	µg/L	774	400	<25	127	371	<25	<25	330	312	<25	101	263	<25	<25	877	377	84
		-	-	-	-	-	-	-	-	-	-	85	275	<25	<25	-	-	-
Fe (soluble)	µg/L	768	<25	<25	-	-	-	-	629	<25	<25	-	-	-	-	790	67	74
Mn (total)	µg/L	12.0	7.8	6.6	4.4	6.0	5.6	5.6	6.0	6.1	8.8	4.7	6.1	7.3	7.2	10.7	6.4	9.9
		-	-	-	-	-	-	-	-	-	-	4.5	6.0	7.3	7.3	-	-	-
Mn (soluble)	µg/L	12.0	6.9	6.6	-	-	-	-	9.3	5.4	8.7	-	-	-	-	10.1	5.9	9.5

Table B-1. Analytical Results from Treatment Plant Sampling at Geneseo Hills Subdivision, Geneseo, IL (Continued)

Sampling Date		04/22/09				05/06/09			05/20/09				06/10/09			06/24/09				07/07/09 ^(b)		
Sampling Location	Parameter	IN	AC	TA	TB	IN	AC	TT	IN	AC	TA	TB	IN	AC	TT	IN	AC	TA	TB	IN	AC	TT
Bed Volume	10 ³	-	-	21.5	22.2	-	-	22.6	-	-	22.9	23.7	-	-	24.6	-	-	25.0	25.8	-	-	26.3
Alkalinity (as CaCO ₃)	mg/L	387	387	389	387	365	374	377	401	396	396	404	394	387	391	394	378	392	378	392	392	390
Ammonia (as N)	mg/L	1.3	0.9	1.0	0.9	1.3	1.2	1.2	1.3	0.9	0.9	0.9	1.2	0.9	0.9	1.3	0.9	0.9	0.9	1.2	0.9	0.9
Fluoride	mg/L	-	-	-	-	0.4	0.4	0.8	-	-	-	-	0.3	0.3	0.2	-	-	-	-	0.4	0.3	0.8
Sulfate	mg/L	-	-	-	-	0.1	0.3	0.4	-	-	-	-	<0.1	0.3	0.3	-	-	-	-	0.2	0.3	0.3
Nitrate (as N)	mg/L	-	-	-	-	<0.05	<0.05	<0.05	-	-	-	-	<0.05	<0.05	<0.05	-	-	-	-	<0.05	<0.05	<0.05
P (as P)	µg/L	51.6	52.3	<10	<10	49.2	51.4	<10	59.2	53.5	<10	34.9 ^(a)	56.2	54.6	<10	51.3	46.3	<10	<10	43.4	44.8	<10
Silica (as SiO ₂)	mg/L	23.3	23.6	23.2	23.3	25.3	25.1	20.8	24.3	24.5	24.6	25.2	24.5	24.1	24.0	23.4	23.7	23.2	23.1	23.7	23.5	23.9
Turbidity	NTU	2.1	0.6	0.1	0.2	8.4	0.9	0.3	2.6	1.2	0.6	1.2	9.2	1.9	0.9	1.9	0.9	0.2	0.2	2.8	1.4	0.4
TOC	mg/L	-	-	-	-	1.7	1.6	1.6	-	-	-	-	1.6	1.6	1.6	-	-	-	-	2.1	1.9	1.9
pH	S.U.	7.3	7.3	7.3	7.3	7.3	7.3	7.3	7.3	7.3	7.3	7.3	7.4	7.4	7.3	7.4	7.3	7.3	7.3	NA ^(c)	NA ^(c)	NA ^(c)
Temperature	°C	12.5	12.6	12.5	12.5	12.9	13.4	13.4	14.5	14.1	14.1	14.2	12.0	12.0	11.9	12.3	12.5	12.5	12.5	12.2	12.4	12.4
DO	mg/L	0.9	1.3	1.2	1.3	0.8	1.1	1.1	0.8	1.2	1.7	1.0	0.6	1.6	1.5	1.0	1.4	1.4	1.3	0.7	1.4	1.3
ORP	mV	-47	331	428	405	-41	245	269	-56	424	440	460	-71	276	256	-45	259	269	287	NA ^(c)	NA ^(c)	NA ^(c)
Free Chlorine (as Cl ₂)	mg/L	-	0.3	0.2	0.4	-	0.2	0.7	-	2.5	0.2	0.2	-	0.9	1.5	-	0.4	0.6	0.2	-	0.4	0.9
Total Chlorine (as Cl ₂)	mg/L	-	2.6	3.2	3.2	-	1.4	1.3	-	3.4	3.2	3.9	-	3.4	3.0	-	2.4	2.4	2.9	-	2.8	3.0
Total Hardness (as CaCO ₃)	mg/L	-	-	-	-	324	338	346	-	-	-	-	362	369	372	-	-	-	-	436	452	457
Ca Hardness (as CaCO ₃)	mg/L	-	-	-	-	177	183	188	-	-	-	-	220	217	220	-	-	-	-	237	251	251
Mg Hardness (as CaCO ₃)	mg/L	-	-	-	-	148	155	158	-	-	-	-	142	152	152	-	-	-	-	199	201	206
As (total)	µg/L	19.7	20.0	0.7	0.6	18.2	17.8	0.5	21.9	21.4	1.8	10.8 ^(a)	19.5	18.6	0.6	19.5	19.0	0.5	0.5	21.1	20.6	0.8
As (soluble)	µg/L	-	-	-	-	17.3	9.3	0.6	-	-	-	-	18.2	9.0	0.5	-	-	-	-	21.4	9.5	0.9
As (particulate)	µg/L	-	-	-	-	1.0	8.5	<0.1	-	-	-	-	1.2	9.6	<0.1	-	-	-	-	<0.1	11.1	<0.1
As(III)	µg/L	-	-	-	-	11.9	0.9	0.3	-	-	-	-	14.8	0.5	0.4	-	-	-	-	17.1	0.6	0.5
As(V)	µg/L	-	-	-	-	5.3	8.3	0.3	-	-	-	-	3.5	8.5	<0.1	-	-	-	-	4.4	8.9	0.3
Fe (total)	µg/L	1,329	468	<25	<25	930	383	33	536	336	<25	310 ^(a)	260	340	<25	433	309	<25	<25	562	394	<25
Fe (soluble)	µg/L	-	-	-	-	399	37	33	-	-	-	-	217	<25	<25	-	-	-	-	280	<25	<25
Mn (total)	µg/L	13.2	6.8	5.2	5.1	12.5	6.9	8.1	8.2	6.2	7.4	9.4 ^(a)	5.5	6.5	5.5	10.3	6.5	4.7	6.0	9.9	7.7	6.5
Mn (soluble)	µg/L	-	-	-	-	6.2	6.7	10.2	-	-	-	-	5.3	5.8	5.8	-	-	-	-	10.2	6.7	6.3

(a) Re-analyzed results similar to original measurements.

(b) Water quality measurements and BV reading collected on 07/08/09.

(c) Substitute operator did not collect pH and ORP measurements on 07/08/09.

Table B-1. Analytical Results from Treatment Plant Sampling at Geneseo Hills Subdivision, Geneseo, IL (Continued)

Sampling Date		07/22/09				08/25/09 ^(a)			09/30/09			10/21/09			11/18/09			12/16/09		
Sampling Location	Parameter Unit	IN	AC	TA	TB	IN	AC	TT	IN	AC	TT	IN	AC	TT	IN	AC	TT	IN	AC	TT
Bed Volume	10^3	-	-	26.6	27.4	-	-	28.8	-	-	30.5	-	-	31.5	-	-	33.0	-	-	34.2
Alkalinity (as CaCO ₃)	mg/L	372	379	374	372	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Ammonia (as N)	mg/L	1.3	1.0	1.0	1.0	1.2	0.9	0.9	1.3	0.9	1.0	1.3	1.1	1.1	1.2	1.0	1.0	1.3	1.1	1.1
Fluoride	mg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Sulfate	mg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Nitrate (as N)	mg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
P (as P)	µg/L	70.2	68.1	<10	<10	48.7	47.4	<10	49.6	44.9	<10	25.8	19.4	<10	<10	<10	<10	52.6	51.7	<10
Silica (as SiO ₂)	mg/L	25.0	25.1	25.4	25.2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Turbidity	NTU	1.1	0.5	1.1	0.9	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TOC	mg/L	-	-	-	-	1.8	1.8	1.8	1.5	1.6	1.5	1.8	1.7	1.6	1.5	1.5	1.5	1.5	1.7	1.8
pH	S.U.	7.1	7.1	7.1	7.1	7.0	7.0	7.1	7.0	7.1	7.1	7.1	7.1	7.1	7.0	7.0	7.2	7.0	7.1	7.1
Temperature	°C	12.5	12.5	12.5	12.5	12.7	12.8	12.8	11.8	12.2	12.3	11.0	11.1	11.3	10.5	10.8	10.8	9.8	10.0	10.1
DO	mg/L	0.7	1.8	1.8	1.7	0.7	1.3	1.5	0.6	1.4	1.4	0.7	1.5	1.4	0.8	1.3	1.3	0.4	1.5	1.5
ORP	mV	-93	255	303	301	-55	272	279	-55	330	298	-35	202	205	-34	241	259	-68	280	377
Free Chlorine (as Cl ₂)	mg/L	-	2.2	1.7	1.9	-	0.3	1.8	-	0.4	1.2	-	0.8	0.6	-	1.3	1.5	-	0.8	1.3
Total Chlorine (as Cl ₂)	mg/L	-	2.9	2.8	2.9	-	2.9	2.4	-	3.2	2.6	-	1.4	1.3	-	2.2	2.1	-	1.9	2.0
Total Hardness (as CaCO ₃)	mg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Ca Hardness (as CaCO ₃)	mg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Mg Hardness (as CaCO ₃)	mg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
As (total)	µg/L	18.5	17.2	<0.1	<0.1	17.6	17.4	0.9	21.4	20.9	1.0	19.3	18.5	0.5	16.8	16.4	0.8	17.7	17.0	0.8
As (soluble)	µg/L	-	-	-	-	18.0	10.8	1.1	19.5	10.2	0.8	16.7	9.2	0.3	16.7	10.5	0.8	18.3	11.9	0.7
As (particulate)	µg/L	-	-	-	-	<0.1	6.6	<0.1	1.9	10.7	0.2	2.6	9.3	0.2	<0.1	5.9	<0.1	<0.1	5.1	0.1
As(III)	µg/L	-	-	-	-	15.5	0.6	0.5	14.1	0.5	0.4	14.1	0.3	<0.1	12.9	0.7	0.6	14.0	0.6	0.4
As(V)	µg/L	-	-	-	-	2.5	10.2	0.5	5.4	9.7	0.4	2.6	8.9	0.2	3.8	9.8	0.2	4.3	11.3	0.3
Fe (total)	µg/L	578	367	<25	<25	974	338	<25	250	280	<25	761	307	<25	315 ^(b)	273	<25	459	278	<25
Fe (soluble)	µg/L	-	-	-	-	542	62	<25	195	<25	<25	599	<25	<25	527 ^(b)	64	<25	209	40	<25
Mn (total)	µg/L	10.4	7.4	6.0	6.1	11.7	5.7	5.5	5.3	6.0	6.4	9.8	5.5	9.1	6.1 ^(b)	5.4	6.3	8.0	6.0	6.0
Mn (soluble)	µg/L	-	-	-	-	7.5	5.0	5.5	5.1	5.2	6.4	8.6	5.2	9.3	8.3 ^(b)	5.1	6.3	8.3	5.4	6.1

(a) Water quality measurements and BV reading collected on 08/26/09.

(b) Re-analyzed results similar to original measurements.

Table B-1. Analytical Results from Treatment Plant Sampling at Geneseo Hills Subdivision, Geneseo, IL (Continued)

Sampling Date		01/13/10			02/10/10			03/10/10			04/07/10			05/05/10		
Sampling Location	Parameter	IN	AC	TT	IN	AC	TT	IN	AC	TT	IN	AC	TT	IN	AC	TT
	Unit															
Bed Volume	10 ³	-	-	35.8	-	-	37.3	-	-	38.5	-	-	39.8	-	-	41.1
Alkalinity (as CaCO ₃)	mg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Ammonia (as N)	mg/L	1.2	1.2	1.2	1.2	1.0	1.0	1.3	1.1	1.1	1.1	0.9	1.0	1.0	1.0	1.0
Fluoride	mg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Sulfate	mg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Nitrate (as N)	mg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
P (as P)	µg/L	44.4	47.9	<10	51.4	50.8	<10	48.9	42.8	<10	39.8	29.5	<10	42.5	45.3	<10
Silica (as SiO ₂)	mg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Turbidity	NTU	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TOC	mg/L	1.9	1.9	2.5	1.8	2.8	1.8	2.0	1.8	1.8	2.0	1.9	2.0	1.9	1.9	1.9
pH	S.U.	NA	NA	NA	NA	NA	NA	7.0	7.1	7.1	7.0	7.0	7.2	7.0	7.0	7.0
Temperature	°C	NA	NA	NA	NA	NA	NA	9.0	10.0	10.0	9.8	10.0	10.2	10.2	10.3	10.5
DO	mg/L	NA	NA	NA	NA	NA	NA	0.3	1.3	1.1	0.5	1.4	1.4	0.9	1.3	1.2
ORP	mV	NA	NA	NA	NA	NA	NA	-58	324	361	-52	394	421	-52	302	350
Free Chlorine (as Cl ₂)	mg/L	-	0.3	0.2	-	1.1	1.4	-	1.1	0.4	-	0.3	0.8	-	0.3	0.3
Total Chlorine (as Cl ₂)	mg/L	-	0.9	0.9	-	1.9	1.9	-	2.3	2.2	-	2.2	1.9	-	1.0	0.7
Total Hardness (as CaCO ₃)	mg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Ca Hardness (as CaCO ₃)	mg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Mg Hardness (as CaCO ₃)	mg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
As (total)	µg/L	17.0	17.1 ^(a)	0.8	16.8	16.4	0.9	16.4	14.9	0.9	17.7	17.2	0.8	16.2	16.7	0.8
As (soluble)	µg/L	17.0	17.0 ^(a)	0.8	16.8	10.6	0.9	16.1	9.2	0.9	16.6	10.1	0.8	16.4	11.2	0.7
As (particulate)	µg/L	<0.1	<0.1 ^(a)	<0.1	<0.1	5.8	<0.1	0.3	5.7	<0.1	1.1	7.1	<0.1	<0.1	5.5	<0.1
As(III)	µg/L	14.7	12.9 ^(a)	0.5	13.2	0.8	0.6	14.3	0.3	0.2	14.2	0.6	0.4	14.3	0.5	0.3
As(V)	µg/L	2.4	4.1 ^(a)	0.2	3.6	9.8	0.3	1.8	8.9	0.7	2.4	9.5	0.5	2.1	10.7	0.4
Fe (total)	µg/L	203 ^(a)	245	<25	191 ^(a)	264	<25	196	297	<25	244	318	<25	590	215	<25
Fe (soluble)	µg/L	761 ^(a)	150	<25	589 ^(a)	39	<25	221	<25	<25	640	27	<25	592	28	<25
Mn (total)	µg/L	4.8 ^(a)	4.9	4.2	4.4 ^(a)	5.2	4.4	4.9	5.3	5.6	5.6	6.4	5.7	7.8	4.7	5.7
Mn (soluble)	µg/L	9.8 ^(a)	5.2	4.2	8.1 ^(a)	4.9	4.4	5.0	4.9	5.6	8.5	5.3	6.0	7.9	4.5	5.5

(a) Re-analyzed results similar to original measurements. On 01/13/10, 02/10/10, 04/07/10, and 06/09/10, soluble iron and manganese results greater than respective total iron and manganese results.

Table B-1. Analytical Results from Treatment Plant Sampling at Geneseo Hills Subdivision, Geneseo, IL (Continued)

Sampling Date		06/09/10			06/30/10			07/28/10		
Sampling Location	Parameter	IN	AC	TT	IN	AC	TT	IN	AC	TT
Bed Volume	10^3	-	-	43.0	-	-	44.1	-	-	45.7
Alkalinity (as CaCO ₃)	mg/L	-	-	-	-	-	-	-	-	-
Ammonia (as N)	mg/L	1.3	1.1	1.1	1.3	1.1	1.2	1.3	1.1	1.1
Fluoride	mg/L	-	-	-	-	-	-	-	-	-
Sulfate	mg/L	-	-	-	-	-	-	-	-	-
Nitrate (as N)	mg/L	-	-	-	-	-	-	-	-	-
P (as P)	µg/L	58.0	50.0	11.6	45.2	45.8	<10	49.2	49.3	<10
Silica (as SiO ₂)	mg/L	-	-	-	-	-	-	-	-	-
Turbidity	NTU	-	-	-	-	-	-	-	-	-
TOC	mg/L	2.9	2.0	2.2	1.8	2.2	2.4	2.0	2.2	3.0
pH	S.U.	7.0	7.1	7.1	7.0	7.0	7.0	6.9	7.0	7.0
Temperature	°C	10.1	10.1	10.1	11.0	12.0	12.0	10.9	12.0	12.3
DO	mg/L	0.6	1.4	1.3	0.7	1.3	1.5	0.6	1.5	1.7
ORP	mV	-54	326	426	-40	397	338	-45	305	345
Free Chlorine (as Cl ₂)	mg/L	-	0.9	0.5	-	0.2	0.5	-	0.4	0.9
Total Chlorine (as Cl ₂)	mg/L	-	2.2	2.1	-	1.9	1.9	-	1.7	1.6
Total Hardness (as CaCO ₃)	mg/L	-	-	-	-	-	-	-	-	-
Ca Hardness (as CaCO ₃)	mg/L	-	-	-	-	-	-	-	-	-
Mg Hardness (as CaCO ₃)	mg/L	-	-	-	-	-	-	-	-	-
As (total)	µg/L	22.6	20.1	2.2	15.9	16.8	0.9	16.3	16.3	1.0
As (soluble)	µg/L	18.8	11.7	1.3	16.9	12.8	1.0	17.1	11.3	1.0
As (particulate)	µg/L	3.9	8.4	0.9	<0.1	4.0	<0.1	<0.1	5.0	<0.1
As(III)	µg/L	14.4	0.4	0.4	13.6	0.4	0.3	13.0	0.5	0.4
As(V)	µg/L	4.4	11.3	0.9	3.3	12.4	0.7	4.2	10.9	0.6
Fe (total)	µg/L	170	254	35	264	204	<25	331	226	<25
Fe (soluble)	µg/L	428	31	<25	243	<25	<25	312	<25	<25
Mn (total)	µg/L	5.4	5.7	6.3	5.9	5.1	4.9	6.4	5.5	5.9
Mn (soluble)	µg/L	8.0	5.5	6.1	7.3	4.8	4.6	6.8	5.1	5.6